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SPECIAL STUDY 3-53-1

SAVA RIVER

ARTIFICIAL FLOODING POTENTIALITIES

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PREPARED BY
MILITARY HYDROLOGY R&D BRANCH
ENGINEERING DIVISION
WASHINGTON DISTRICT, CORPS OF ENGINEERS
WASHINGTON, D. C.
APRIL 1953

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SPECIAL STUDY S-53-1

SAVA RIVER
ARTIFICIAL FLOODING POTENTIALITIES

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ARTIFICIAL FLOODING POTENTIALITIES SAVA RIVER

SECTION I
INTRODUCTION

1-01 ASSIGNMENT.

This special study was assigned to the Military Hydrology R&D Branch, Engineering Division, Washington District by letter from Office, Chief of Engineers, ENGWE, to the Division Engineer, North Atlantic Division: subject "Military Hydrology R&D Project No. 8-72-12-001: Special Assignment" dated 9 January 1953.

1-02 PURPOSE AND SCOPE.

a. This report presents information regarding the hydraulic nature of artificial flooding potentialities in the SAVA (SAVE)*, River basin. It covers that portion of the SAVA River upstream from the confluence of the VRBAS River. Particular emphasis is placed on the region near the important communication center of LJUBLJANA.

b. The report consists largely of a compilation and consolidation of information presented in various intelligence documents and technical publications, with certain supplementary analyses and discussions. The material forming the basis of this report was limited to that available in the Washington, D. C. area. Additional data from other sources and field reconnaissance are needed to adequately cover the subject for general military requirements.

c. The report is designed to furnish basic data and results of analyses needed to answer questions concerning:

(1) Normal and extreme discharges, stages, and velocities at key stations on the SAVA and LJUBLJANA Rivers.

(2) Stream characteristics including gradients, depths, and widths of channel and flood-plain on those streams.

(3) Data concerning locations and zero elevations of gaging stations.

(4) Data concerning locations and dimensions of dams and bridges.

(5) The extent of flooding possible by erection of temporary dams on the LJUBLJANA River and on the SAVA River upstream from the confluence of the VRBAS River.

* Common English and Yugoslavian spelling is SAVA; Austrian spelling is SAVE

1-02

(6) The magnitude and duration of flood waves and flow variations created by breaching or regulated discharge from the dams and reservoirs and the effect on military bridging and crossing operations on the SAVA River.

1-03 ARRANGEMENT.

This report is sub-divided as follows:

Section I	Introduction
Section II	Drainage Basin Characteristics and Developments
Section III	Hydrologic Characteristics
Section IV	Artificial Flood Potentialities
Section V	Effect on Military Operations
Bibliography	
Tables	
Plates	
Exhibit A	Abstracts of Technical Literature on the SAVA River
Exhibit B	Abstracts of Technical Literature on MOSTE DAM

1-04 DEFINITIONS AND REFERENCE DATUM.

a. Equivalent English-Metric Terms. Most values used in this report are in the Metric System. Conversion factors for the English and Metric systems are presented for convenient reference in Table 1.

b. Abbreviations. The following abbreviations are used in this report:

cm	centimeters
km	kilometers
km^2	square kilometers
l	liters
m	meters
mm	millimeters
m/sec	meters per second
m^3	cubic meters
m^3/sec	cubic meters per second

c. Hydrologic Terms. Special hydrologic abbreviations, in conformance with standard German and Austrian hydrologic practice, are defined in Table 2.

d. Elevation Datum. Elevations are in meters above the Adriatic Sea, "meters uber Adria" (m.u.A.), the old Austrian altitude datum.

e. River Distances. In this report, distances are expressed as kilometers upstream from the confluence of the SAVA and DANUBE Rivers at BELGRADE.

f. Grid System. Grid references cited in this report are to the "Universal Transverse Mercator" (U.T.M.) Grid system unless otherwise designated.

g. Maps. The area of the SAVA River basin is covered by the following available standard American-British military maps:

Scale	Map Series	Sheet Numbers
1:250,000	M591, GSGS 4230	7B
do	M506, GSGS 4413	Y2, Y3, Y13-Y17
1:100,000	M691, GSGS 4164	14A, 14B, 26, 26A
do	M607, GSGS 4396	10-12, 28-30, 45-49, 65-69
1:50,000	M791, GSGS 4229	14AII, 14BII-III, 26I, 26AI-IV
do	M702, GSGS 4734	11II-III, 12II-III, 26I-IV, 28I-IV, 29I-IV, 30III, 45I-IV, 46II-IV, 47II-III, 48II-III
1:25,000* do	JUGOSLAVIA & DEUTSCHE HEERESKARTE	TOLMIN 2a-b; BLED 1a-d, 2a-d; LJUBLJANA 1c, 3a-d, 4c-d; CELJE 3c-d; CERKNICA 1a-b; VRHNIKA 2b

1-05 REFERENCES.

All references cited in this report are listed in the Bib. ...aphy following Section V of the text.

* U. S. maps in this scale not now available.

SECTION II

DRAINAGE BASIN CHARACTERISTICS AND DEVELOPMENTS

2-01 GENERAL.

a. The SAVA River rises in the JULIAN ALPS in the extreme northwest corner of Yugoslavia. It is formed by the confluence of the SAVA DOLINKA (WURZNER SAVE)* and SAVA BOHINJKA (WOCHEINER SAVE)* Rivers near RADOVLJICA (RADMANNSDORF).* The river flows generally eastward for about 940 km to join the DANUBE River at BELGRADE. Many large tributaries flow from the south into the SAVA River; notably the KUPA, UNA, VRBAS, BOSNA and DRINA Rivers. The left bank tributaries are short and unimportant. The SAVA River is an important navigable waterway for 593 km upstream to SISAK. Important highway and railway lines follow the stream valleys of the SAVA River basin through the mountainous terrain of northwest YUGOSLAVIA. A number of hydro-electric power plants are located on the headwaters of the main river and its tributaries. A general map is presented as Plate 1 and detailed descriptions are contained in the documents listed in the Bibliography as References 1 to 5, inclusive.

b. This report considers primarily the main stem of the SAVA River upstream from the confluence of the VRBAS River, although certain available information on the lower reaches and on important tributaries is included.

2-02 TOPOGRAPHY.

The source of the SAVA River is located in a manner common in alpine regions, i.e. on the floor of a through valley rather than on a mountain crest or divide. The headwaters lie in glaciated valleys of the JULIAN ALPS in a region of almost perpetual snow cover. The stream emits from the alpine region into the large LJUBLJANA basin, and thence through a deep, narrow gorge into a flat rolling region above ZAGREB. The lower reaches meander across the flat marshy plains of the POSAVINA valley and MIDDLE DANUBE plain. Reference is made to Plate 2 for a physiographic diagram and to Exhibit A and References 4 through 10 for detailed topographic information.

2-03 GEOLOGY.

The upper reaches of the SAVA River in Slovenia lie in a deep glaciated valley floored with gravel deposits and containing narrow alluvial river-flats. The part in the LJUBLJANA Basin, south of the town of LJUBLJANA, is a level marshy plain. That basin has an extensive drainage system to relieve the prevalent soggy ground conditions, which are caused in large part by seepage of underground water from the so-called KARST REGION, a weathered limestone area to the west of this basin. (See Plate 3 and Exhibit A.) The SAVA River passes out of the calcareous mountain region through a deep

* Yugoslavian name (old Austrian name).

gorge near LITIJA (km 813). In the lower reaches, SE of ZAGREB (km 700), the wide river-flats are composed of loess and river alluvial sand deposits covering the older coarse gravel terraces. Detailed description of the geology may be found in Exhibit A and in References 5 through 7.

2-04 DRAINAGE AREAS.

The total drainage area of the SAVA River is approximately 95,000 km^2, representing nearly 40 percent of the entire territory of Yugoslavia. At BELGRADE its drainage area is about one-third of that of the DANUBE River, through it carries more discharge in flood than the latter at their junction. The drainage areas at key gaging stations is shown in Table 3; a tabulation of areas drained by the SAVA River and its major tributaries follows:

River	Location	Drainage Area (km^2)
LJUBLJANA	Mouth	1,900
KUPA	do	11,449
UNA	do	7,793
VRBAS	do	5,424
DRINA	do	19,877
SAVA	RADOVLJICA (km 893)	888
do	LITIJA (km 813)	4,967
do	ZAGREB (km 700)	12,500
do	Mouth	95,436

2-05 GRADIENTS AND PROFILES

The gradient of the SAVA River is steep in the upper mountainous reaches and very gradual in the lower reaches below ZAGREB, as may be seen on the stream profile of Plate 4. The slope of the LJUBLJANA River, however, is flatter in the upper than in the lower reaches, being about 0.6 per 10,000 in the flat moorland upstream of LJUBLJANA and 9 per 10,000 below that town, as shown by the Plate 5 stream profile. A tabulation of average gradients on the SAVA River follows:

Reach	River km	Average gradient per 10,000
JAVORNIK-RADOVLJICA	908-893	98
RADOVLJICA-ZAGREB	893-700	14
ZAGREB-SISAK	700-593	3
SISAK-BELGRADE	593- 0	0.2

2-06 CHANNEL DEPTHS.

The depth of the SAVA River is quite variable; at mean water, depths generally average from 1 to 5 m in the upper reaches and from 3 to 8 m in the regulated lower reaches. In some places, deep spots up to nearly 20 m deep exist in the stream bed; in others, shoals and bars abound. Reference is made to additional depth data

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[illegible] - [illegible] Series No. Y.2 [illegible]

Type:- Sheet No. [illegible]

Serial No.	Location and Map Ref.	Information Source & Photo Quality	Item.	Width of Bed.	Wet Gap with Date.	Bed	Depth	Current	Banks - Width & Depth.	Approach Roads and Surrounding Terrain.	Remarks.
11.	[illegible] [illegible]	[illegible] [illegible]-72.	Road Bridge. Steel Girder Truss.	270'	270'	Rock and Sand			Steep.	[illegible] angle approaches [illegible] hilly terrain on both sides.	Single span steel girder bridge. Span 27[illegible]'. Clear width [illegible]'. The br is situated in a steep valley. Building site restricted.
[illegible]	[illegible]	[illegible]-452 [illegible]	Road Bridge 3(?) spans. Masonry Arches.	175'	[illegible]' ([illegible])	Rock & Sand.			Steep.	[illegible] angle approaches to bridge. Hilly wooded terrain.	Overall length [illegible]'. [illegible]
13.	[illegible] [illegible]1267	[illegible]-452 [illegible]-3	Footbridge (?) 3 Spans (?)	165'	130'					[illegible] angle approaches to bridge.	Overall length [illegible]'. Clear width 10'.

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TABLE 5
5 of 16

contained in References 8, 10, and 13 and to the depth profile presented on Plate 17. The range of normal depths along the SAVA River appears in the following table:

Reach	River km	Depth at MW (m)
JAVORNIK-RADOVLJICA	908-893	0.5-2
RADOVLJICA-ZAGREB	893-700	1-5
ZAGREB-SISAK	700-593	5-6
SISAK-BELGRADE	593- 0	6-8

2-07 CHANNEL AND FLOOD-PLAIN WIDTHS.

Above ZAGREB (km 700), the stream width ranges from 3 to nearly 200 m. The flood-plain is narrow, being less than 300 m wide except at a few localities where it widens to as much as 4 km. Below ZAGREB, the channel widens to nearly 700 m in places. Along the flat plains in the lower reaches of the river, extensive areas are subject to frequent and prolonged inundation as described in detail in References 6, 8, 10, and 13. There, backwater also extends up the tributary streams for great distances. A profile of channel and flood-plain widths is presented as Plate 6, and a tabulation of representative widths is given below:

Reach	River km	Channel Width (m)	Flood-Plain Width (m)
JAVORNIK-RADOVLJICA	908-893	3- 30	30- 300
RADOVLJICA-ZAGREB	893-700	50-200	100- 4,000
ZAGREB-SISAK	700-593	100-200	1,000-10,000
SISAK-BELGRADE	593- 0	150-170	500-20,000

2-08 NAVIGATION.

The SAVA River is navigable from BELGRADE upstream to the confluence of the KUPA River near SISAK (km 593). Construction has been started on a canalization project to permit navigation to be extended to ZAGREB (km 700). Tributaries, navigable for short distances, include the KUPA, UNA, BOSNA, DRINA, and BOSUT Rivers. The "standard" 1000-ton (metric) Danube barges drawing about 2 m can now reach BROD (km 367) and occasionally as far as SISAK on the SAVA River. The extent of navigation on the tributaries is doubtful, but is probably limited to craft of about 100 metric tons, drawing about 1 m. Detailed information is contained in References 2, 3 or 5.

2-09 REGULATION.

At the present time there are no known existing reservoirs in the SAVA River basin providing significant storage for flood-control, irrigation, or navigation. The hydro-electric power reservoirs located within the area do not have sufficient storage capacity to exert any appreciable regulatory effect upon

the flow of the SAVA River and its tributaries. Considerable variations between high and low flows prevail. Remedial measures have been confined to dredging of the stream and to construction of levee systems.

2-10 DAMS AND RESERVOIRS.

a. Reservoirs. No large artificial reservoirs exist in the SAVA River basin, although a number of possible future storage developments are reported to be under consideration (See Exhibit A or Reference 14). Exact locations of these proposed projects are uncertain. Some water retained in the "polje" of the karst region, flows underground into the LJUBLJANA Basin, as indicated on Plate 3 and described in Exhibit A and in References 11, 12, and 13. Considerable natural storage of water exists in the form of snow retention in the mountainous headwaters. Flows from melting snow continue well into the late spring.

b. Hydro-electric Dams. Numerous hydro-electric projects are located on the tributaries of the SAVA River. Many others are proposed or under construction. However, information is not now available as to the exact locations, state of completion, or the dimensions and details of the dams and associated hydraulic structures of most of the projects. It may be assumed that the storage capacity is, in most cases, rather small; since most hydro-electric plants in the rugged terrain of YUGOSLAVIA depend on high head rather than on volume of discharge to generate electric power. Some additional information on Yugoslavian electric power development may be found in Reference 23 (National Intelligence Survey No. 21). Fragmentary data also is scattered in various classified intelligence documents. Detailed description of the MOSTE DAM, a hydro-electric project located on the SAVA DOLINKA River about 4 km downstream of JAVORNIK (km 908), is contained in Exhibit B of this report. That exhibit consists of translated excerpts from Reference 14. Sketches illustrating details of the MOSTE DAM appear on Plate 7. A tabulation listing the more important hydro-electric projects, as compiled from various intelligence sources, is presented as Table 4.

c. Navigation Locks and Dams. There are no navigation locks or dams on the SAVA River or its tributaries.

d. Mill Dams. Many small mill dams are located on the streams of the SAVA River basin upstream of the navigable reaches. They store small amounts of water for local industrial use. Those located on the LJUBLJANA River in and downstream of the town of LJUBLJANA, and also other dams on other streams may contain small locks or other facilities for the passage of small local boat traffic.

2-11 LEVEES.

A number of short low levees have been built to protect local communities against the frequent extensive flooding prevalent on the plains and flats of the lower reaches of the SAVA River.

These levees have not been integrated into a complete levee system. Accurate up-to-date information concerning the levees was not available.

2-12 CANALS.

There are no important navigation canals in the SAVA River basin. The LJUBLJANA Basin has an extensive drainage canal system. A large complex drainage and irrigation canal system is being built in the flat plain region of the lower SAVA River, as noted in Exhibit A.

2-13 LAKES, PONDS, AND MARSHES.

a. Lakes. There are two large important lakes in the headwater region of the SAVA River: (1) the BOHINJSKO JEZERO (WOCHEINER SEE) near the source of the SAVA BOHINJKA (WOCHEINER SAVE) River; and (2) the BLEDSKO JEZERO (VELDESER SEE), commonly known as LAKE BLED, near the confluence of the two forks of the upper SAVA River. The former covers 3.283 km^2, is nearly 40 m deep, and has a 1 km wide ice sheet along the east bank during January and February. LAKE BLED covers only about 1.4 km^2, is but 10 m deep, and becomes completely frozen over during that same period.

b. Ponds and Marshes. The LJUBLJANA Basin was formerly a very soggy marshland, but an extensive drainage system has relieved the swampy conditions sufficiently to permit cultivation of a large part of the area. Many large swamps occur along the lower reaches of the SAVA River. Much of the flat lowlands in that region is subject to ponding during a large part of the year. Detailed description may be found in Exhibit A or in References 5 to 10, inclusive.

2-14 BRIDGES.

Reliable information with respect to post-war bridge reconstruction was not available in this office at this time; however, a tabulation of available bridge data extracted from Reference 1 is presented in Table 5. Locations are indicated on Plate 8.

SECTION III
HYDROLOGIC CHARACTERISTICS

3-01 GENERAL.

a. Information regarding river stage, discharge, flow duration and velocity are presented in generalized graphical form insofar as practicable to facilitate application of the data to specific military problems. The cited references should be utilized for supplementary data.

b. Available long-term and recent hydrologic records for YUGOSLAVIA are scanty and incomplete. For much of the data, reliance had to be placed mostly upon old official publications of the Austrian-Hungary Empire, published prior to World War I. The frequent complex political and territorial changes in that area has handicapped the collection, publication, and dissemination of hydrologic data.

3-02 CLIMATOLOGY.

The climate of the SAVA River basin is transitional between the continental and coastal climatic types. In general, it is wetter and cooler in the mountainous upper reaches of the river than on the plains of the lower reaches. There is considerable snow in the mountains. Heavy rains occur during the late summer and early autumn, reaching a maximum in October. The upper SAVA River freezes in extreme winters where the stream velocity is low; the lower SAVA River only occasionally is closed by ice, usually never earlier than 4 December nor later than 25 February. Rainfall records are published annually in Reference 15; detailed data on climate are contained in References 16 and 17. The seasonal variation in precipitation is illustrated in the following tabulation based on data in Reference 17:

Mean Precipitation (Inches)

	LJUBLJANA (Km 852)	ZAGREB (Km 700)	BELGRADE (Km 0)
Jan.	2.9	1.8	1.3
Feb.	2.7	1.9	1.2
Mar.	3.9	2.2	1.6
Apr.	3.9	2.8	2.4
May	4.3	3.1	2.8
Jun	5.7	3.9	3.0
Jul	5.5	3.2	2.6
Aug	5.7	3.2	1.9
Sep	5.5	3.4	1.7
Oct	6.6	3.9	2.4
Nov	4.5	3.1	1.9
Dec	4.1	2.6	1.6
Annual	55.4	34.9	24.4
Years Record	-	64	33

3-03 STREAM GAGING STATIONS.

A number of stream gages have been established on the SAVA River and its tributaries. Stage records and other data for the more important stations may be found in References 13, 18, 19 and 20. Locations of gages on the SAVA and LJUBLJANA Rivers are shown on the General Map, Plate 1, and on the stream-bed profiles, Plates 4 and 5. Pertinent gage data are summarized in Table 3.

3-04 RIVER STAGES.

a. Records. The maximum, mean and minimum stages of record for stations are presented in Table 3. The data shown represent the best available at this time, and were obtained from various sources covering different periods of record. The effect of possible river improvements (especially below ZAGREB) cannot be accurately evaluated.

b. Stage Variations. The range of stage variations is shown for various stations on Plate 9. The unusual double cycle of seasonal variations for the upper SAVA River is illustrated by the monthly mean stage graphs shown on Plates 10 and 11. The spring floods occur in March through May, with the melting of the snows; this is followed by a period of very low stages during the early summer. The intense rains of autumn bring a second period of high stages, while a second period of low stages prevails during the winter when surface run-off is held up in the form of snow. Seasonal variations in mean monthly stage amount to between 1 and 3 m. The appreciable range between high and low stages is shown by the following tabulation, abstracted from Plate 9:

Station	River Km	Range of Stage(m) HHW-NNW	Range of Stage(m) MHW-MNW
RADOVLJICA	893	2.62	2.18
LITIJA	813	6.27	2.83
ZAGREB	700	4.74	3.10
DUBRAVCAK	636	10.38	8.10
BRČKO	225	7.92	5.95

c. Stage Duration. Stage duration curves for several stations on the SAVA and LJUBLJANA Rivers are shown on Plates 12 and 13. These curves show the percent of the time that a given stage may be expected to be equalled or exceeded. The median stage, shown on Plates 12 and 13 as equalled or exceeded 50 percent of the time, should not be confused with the mean stage (representing an arithmetical average) as shown in Table 3 and on Plates 10 and 11. Comparison of mean and median stages follows:

Station	River Km	Mean Stage (cm) (MW) Table 3, Plates 10&11	Median Stage (cm) (50% of time) (Plates 12&13)
SVETI DUH	918	42	34
VRHNIKA	874	-35	-75
LITIJA	813	68	60
ZAGORJE	798	106	50
SEVNICA	763	81	67

3-05 RIVER DISCHARGES.

a. Records. Available published records of river discharges for the SAVA River and its tributaries are practically nonexistent. References 13, 18, and 21 contain a few records of discharge measurements, mean flows, or stage-discharge relations. The discharge data summarized in Table 3 and shown on the discharge profile of Plate 17 represent estimates based on the meager information contained in those references.

b. Stage-Discharge Relation. Average stage-discharge relation curves for key stations on the SAVA and LJUBLJANA Rivers are presented on Plates 14, 15, and 16. These curves were estimated from the scanty discharge measurements and equivalent stage-discharge data contained in References 13, 18, and 21.

c. Discharge Variations. Stream discharge is very variable. It follows the same double seasonal cycle as the stage (see paragraph 3-04). Estimates of mean and extreme discharges are shown on Table 3 and on the discharge profile of Plate 17. Due to the varying period of record, mean discharge is presented as an estimated range covering those periods. The wide range in discharge on the SAVA River may be seen in the following tabulation, as taken from TABLE 5:

Station	River Km	Discharge (m^3/sec) Maximum(HHQ)	Mean(MQ)	Minimum(NNQ)
OTOČE	885	450	44- 72	13
LITIJA	813	1340	152-250	41
ZAGREB	700	1880	230-330	67
BRČKO	225	3540	875-1060	186
BELGRADE	0	4400	1200-1500	260

3-06 RIVER VELOCITIES.

a. General. The velocity of stream flow varies according to the conformation of the river bed, depths, obstructions, restrictions, local variation of slope, etc. Channel improvements and cut-offs, training walls and levees, operation of dams and other modifications of natural conditions appreciably affect the stream velocity. Influent rivers in flood tend to elevate the main river waters at the point of confluence. Accordingly, correlations between river stages and surface velocities at gaging stations cannot be interpreted as applicable to all points along the adjacent river sections, but only serve as general indications.

b. Surface Velocities. Insufficient basic information concerning the stream hydraulic functions (cross-sectional area, wetted perimeter, water surface slope, roughness factor, etc.), was available to permit accurate determination of stream velocities. Estimates were based on velocities observed during discharge measurements at gaging stations as recorded in References 13 and 18, and on average velocities given in References 8 and 10. The observed velocities were assumed to be mean cross-sectional velocities, which were increased by 18 percent to indicate the mean surface velocities. As indicated

in the velocity studies in Reference 22, the mean cross-sectional velocities should be increased by 25 to 75 percent to obtain the maximum surface velocities likely to be encountered during crossing operations. Mean surface velocity ratings at the gaging stations are presented on Plates 14, 15, and 16. Velocity profiles at MW and HHW appear on Plate 17. Mean surface velocities at selected stations are tabulated below:

Station	River Km	Mean Surface Velocities (m/sec) MW	Mean Surface Velocities (m/sec) HHW
JAVORNIK	908	1.2	2.7
LITIJA	813	2.0	2.9
ZAGREB	700	1.2	2.7
RUGVICA	663	0.9	1.3
BRCKO	225	0.7	1.2
BELGRADE	0	0.5	1.6

c. Flood Wave Travel Time. Examination of flood crest times as recorded in the old official Austrian Hydrologic Yearbooks (Reference 18) provided the following estimate for the rate of travel of natural flood waves on the SAVA River:

Reach	River Km	Average travel rate of peak (km/hr.)
JAVORNIK-GLOBOKO	908-888	13
GLOBOKO-KRANJ	888-871	11
KRANJ-SV. JAKOB	871-842	10
SV. JAKOB-SEVNICA	842-763	8
SEVNICA-CATEZ	763-732	7.5

SECTION IV
ARTIFICIAL FLOODING POTENTIALITIES

4-01 GENERAL.

a. The term "artificial flood" as used in this report applies to any major increase in the extent of flooding, over that normally prevailing with existing developments, that is brought about by manipulation of control structures, breaching of dams or levees, or temporary damming operations designed to create flooding conditions. Applications of artificial flooding considered in this report fall into the following four general categories:

(1) Still-water barriers, created by flooding land to form water obstacles, using such means as breaching levees, diverting flow from canals, raising crests of existing dams or constructing temporary dams.

(2) Drainage obstacles or mud-flats, in which the wetness of the soil is increased to form muddy or marshy conditions that would impede military traffic, brought about by disrupting the normal drainage, destroying pumping and drainage facilities used to drain marshy or low land, or by inducing shallow inundation of flood-plains or reclaimed land. Mud-flats may also be formed by draining areas normally inundated by reservoirs or ponds.

(3) Stream flow variations, in which changes in discharges, depths, velocities and widths of streams are brought about to hinder stream-crossing operations or navigation such as might be accomplished by opening and closing outlet works of water control structures.

(4) Major flood waves, created by sudden breaching of a dam to release large quantities of impounded water.

b. Certain opportunities exist for effective use of these artificial floods in the SAVA River basin. This section presents a review of the potentialities and a quantitative evaluation of the hydraulic effects. Reference should be made to Section V for discussion of associated military factors.

c. Brief, generalized estimates of artificial flooding possibilities by Austrian, German, and Hungarian military staffs are included in the documents listed in the Bibliography as References 8, 9, and 10.

4-02 STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. General. The studies reviewed in this paragraph pertain to artificial flooding produced by creation of still-water barriers and drainage obstacles along the SAVA River above the junction of the VRBAS River. The studies were largely based on a map study using 1:25,000 Yugoslav maps and 1:50,000 American maps. Exact determination of elevations, contours, and boundaries from these maps was difficult; however,

the results of this study are believed to offer good indications of the relative possibilities of such flooding. First-hand information should be obtained by local reconnaissance regarding ground elevations and the locations, elevations and dimensions of levees, roadfills and culverts in the vicinity of specific barriers in order to accurately establish the area subject to artificial flooding.

b. Hydrologic Considerations.

(1) The effect of artificial flooding is largely contingent upon the natural hydrologic conditions prevailing at the time of the operation. The volume of water stored and available within the basin, the rate of stream flow and the river stage are important factors. Reference is made to Section III of this report for detailed description.

(2) Attention is directed to the wide range between high and low flows shown in Table 3 and on Plate 17, and to the seasonal variation in discharge illustrated by Plates 10 and 11, and discussed in paragraph 3-05. It should also be noted that official published mean discharges are unavailable and that estimated probable ranges are given in Table 3. Based on these ranges, the following mean discharges were selected for use in this study:

Reach	Selected Mean Discharge (m^3/sec)
LJUBLJANA RIVER	
At LJUBLJANA	50
SAVA RIVER	
JAVORNIK-LJUBLJANA R.	100
KUPA R-UNA R.	200
UNA R-VRBAS R.	600

c. Means of Creating Still-Water Barriers and Drainage Obstacles.

(1) The water obstacle afforded by the existing streams of the SAVA River basin could be increased by utilization of one or more of the following means:

(a) Creation of still-water barriers by construction of temporary dams at bridge-sites, combined with closing of culverts and other openings in levees and road fills.

(b) Inundation of lowlands along the streams by breaching dikes and levees and opening of flood gates in levees.

(c) Inundation of lowlands by closing normal drainage outlets.

(2) In order to obtain a quantitative evaluation of the potential artificial flooding at various locations, analysis was made where possible on barriers resulting from temporary damming to 3 or 4 m above mean water (MW); however, where it seemed evident that the barrier could be appreciably increased, the effect of higher dams was studied.

In this study, it was assumed that the surface of the pools above the temporary dams would be level, and that mean water conditions would prevail at the time of the operation. During high water conditions greater flooding could be expected due to the increased slope of water surface upstream from the temporary dams.

d. Effect of Still-Water Barriers.

(1) General. The effects of artificial flooding created by temporary damming operations on the LJUBLJANA and SAVA River are summarized in Table 6 and the extent of inundation indicated on Plate 18. Serial numbers of sites correspond to the bridge serial numbers of Table 5 and Plate 8. The flooding produced by temporary damming would cover isolated areas ranging from 0.5 to 10 km wide. Formation of continuous overbank flooding, by means of temporary dams, is not considered practicable. Insufficient topographic data were available to permit analysis of the effect of blocking of the outlets of the many small tributaries of the SAVA River. However, it appears probable that such disruption of natural drainage would considerably increase the extent of marshy and swampy areas at many points along the SAVA River and along its tributaries. Review of the effects of still-water barriers and drainage obstacles in specific reaches of the LJUBLJANA and SAVA Rivers follows.

(2) LJUBLJANA RIVER. From its source to the town of LJUBLJANA, the LJUBLJANA River flows through a wide, flat, marshy plain. Erection of temporary dams at the road bridge in LJUBLJANA and at a road bridge on the GRUBER CANAL, to an elevation of 290 m.ü.A. (6.5 m above MW) would cause flooding of virtually the entire valley. The water barrier thus formed would be 18 km long and would average 3.5 km in width. The impounded water could be released to supplement other sources of water supply for still-water barriers in the SAVA valley. Sudden release of the water stored in the LJUBLJANA Basin would create an artificial flood wave as described in paragraph 4-03. Raising the stage of the river to a lesser height would probably raise the ground water level and interfere with the natural drainage of the region. That would form an effective drainage obstacle of the area. Blocking of the numerous drainage ditches, coupled with destruction of pumping facilities and dikes would also recreate marshy conditions.

(3) SAVA River Source to VIZMARJE-TACEN (Km 852). Above TACEN the banks of the SAVA River generally are high and rise steeply from the river bed, thus making flooding by temporary damming operations impracticable. Near TACEN it is probable that the high meadows on the right bank of the stream could be kept in a swampy condition by blocking the natural drainage channels leading to the SAVA River.

(4) VIZMARJE-TACEN to DOLSKO (Km 833). Temporary damming at the railroad bridge near JEZICA (km 849), would produce an isolated still-water barrier approximately 3.5 km long and averaging 1.0-1.3 km wide. At the DOLSKO RR bridge (km 833), temporary damming to elevation 265 m.ü.A. could produce a still-water barrier on the left bank, 3.6 km long and 0.5-0.7 km wide. In both cases the nature of the banks and surrounding ground would probably make it necessary to raise the temporary dams to the full elevation of the bridge decks (7-10 m above MW) in order

to achieve any appreciable flooding. These two bridges probably provide the only suitable sites in this reach.

(5) DOLSKO to VIDEM (km 757). At DOLSKO the SAVA enters a deep narrow gorge which extends to VIDEM (km 757). In this reach still-water barriers would be confined to the narrow valley floor and would probably not afford significant water obstacles.

(6) VIDEM to ZAGREB (km 700). At VIDEM (km 757), the SAVA emerges from the gorge. From there to ZAGREB (km 700) the river banks are fairly high. In this reach a long narrow still-water barrier could be formed by raising a temporary dam 3 to 4 m above MW at the BREZICE RR bridge (km 735). As indicated in Table 6 and on Plate 18, this pool would be 7 km long and average approximately 0.5 km in width. Although no other suitable sites for temporary damming operations exist along the SAVA River in this reach, extensive drainage obstacles could probably be formed near the confluences of the SUTLA River (km 729) and of the KRAPINA River (km 715). Blocking of those streams and of other drainage ditches in the vicinity would cause shallow inundation or boggy conditions in those low-lying marshy areas.

(7) ZAGREB to the confluence of VRBAS River (Km 420). Below ZAGREB (km 700), the SAVA River flows through a wide, flat valley. Between ZAGREB and the VRBAS River confluence there are only three bridges affording possible sites for temporary dams. They are: SISAK Road bridge (km 595), JASENOVAC RR bridge (km 508), and STARA-GRADISKA road bridge (km 460). Erection of temporary dams at those locations would result in the formation of long wide still-water barriers. As indicated in Table 6 and on Plate 18, the pool formed by a temporary dam at SISAK would extend up a large low depression lying several kilometers to the left of the river channel. That pool would be 10 km long and average 4-7 km wide. Blocking the bridges at JASENOVAC and STARA-GRADISKA would form a continuous still-water barrier 60-70 km long and averaging 2 to 10 km wide as indicated in Table 6 and on Plate 18. In this reach the low flat valley drains to the SAVA by many small streams and ditches. Any blocking or interference with this drainage system would probably create extensive drainage obstacles and mud-flats.

c. Water Requirements for Still-Water Barriers.

The volume of water required to effect the artificial flooding on the LJUBLJANA and SAVA Rivers described in the preceding paragraphs and shown in Table 6 and on Plate 18, together with the estimated time required for filling at the assumed average mean rates of flow given in paragraph 402(b), are approximately as follows:

Site	Water Requirement (million m^3)	Filling Time (days)
LJUBLJANA	65	15
JESICA	10	1
DOLSKO	2	1
BREZICE	5	1
SISAK	50- 60	2
JASENOVAC	40- 60	1
STARA-GRADISKA	300-360	6
	472-552	

4-03 MAJOR FLOOD WAVES.

a. General. The studies in this paragraph pertain to artificial flooding that might be produced along the SAVA River by breaching of MOSTE DAM, and of temporary barriers at LJUBLJANA and DOLSKO GORGE. Insufficient data were available to permit studies of the effects of major flood waves from other dams in the area. However, their effect probably would be slight, due to the small size of dams and volume of water stored in the headwater reservoirs upstream of the confluence of the SAVA and VRBAS Rivers.

b. Hydrologic Considerations.

(1) Natural flow conditions in the streams of the SAVA River basin vary considerably, as shown on Plates 9 and 17 and discussed in Section III. The stage and discharge existing at the time of release of artificial flood waves greatly influence the effects. In this study, the assumed base flows in the streams at the start of the waves approximate mean water conditions.

(2) Reservoir pool elevations at the time of release of flood waves also influence the peak and duration of the waves. High pool conditions might be expected during the spring and fall, and low conditions during the summer and winter. Several different reservoir pool elevations were considered in this study, illustrating a wide range of possibilities. The storage curve for MOSTE DAM shown on Plate 19 was derived by the method described in Reference 24. Storage values for the LJUBLJANA and DOLSKO GORGE ponding areas were estimated from 1:25,000 topographic maps. A tabulation of estimated storage capacities and average filling times under mean water conditions follows:

Reservoir	Stage (m.a.s.l.)	Storage (mil. m^3)	Mean Inflow (m^3/sec)	Filling Time (days)
MOSTE DAM	523.5	6.89	16	5
	517	3.4	"	2.5
	514	2.3	"	2
LJUBLJANA Barrier	295	655	50	150
	290	65	"	15
DOLSKO GORGE Barrier	280	325	100	40
	270	83	"	10

(3) During passage of a major flood wave downstream, an appreciable volume is retained behind embankments and in depressions on the flood-plain, and lost through evaporation, seepage, etc. For example, 39.5 percent of the volume of water discharged from the Eder Dam breach of May 1943 was lost in the passage of the flood wave to Intschede, 426.6 km below the dam (See References 25 and 26). Consequently it was assumed in this study that for each 10 km of travel, about 1 percent of the volume within the flood wave would be lost or retained on the flood-plain, where the wave exceeded bankfull stages.

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c. Means of Creating Major Flood Waves.

(1) Breaching of MOSTE DAM. Breaching of this dam (located at km 904) would produce flood waves of limited magnitude in the SAVA River upstream of ZAGREB (km 700). The size of the possible breach is limited, due to the narrow width of the gorge at the damsite, (See Plate V).

For purposes of this study, the breach openings were assumed to be of trapezoidal shape, with side slopes of 2 vertical on 1 horizontal, and bottom widths of 10 m or 20 m, as shown on Plates 20 and 21. Those openings approximate the maximum dimensions feasible at the damsite. It is uncertain whether the elevation of the dam crest is to be left at 514 m.ü.A., (that of the first stage of construction) or is to be raised to 523.5 m.ü.A., the proposed ultimate crest (See Exhibit B). Both levels were considered in this study. Also, study was made of the comparative flood wave effects that would be made possible by raising of the dam crest to 517 m.ü.A. by means of temporary construction.

(2) Breaching of LJUBLJANA Barrier. It would appear possible to erect barriers across the LJUBLJANA River and the GRUBER Canal near their upper junctions just south of the city of LJUBLJANA (km 852). That would permit considerable water to be impounded on the wide flat marshy plain of the LJUBLJANA Basin, as shown on Plate 18. Breaching of those barriers would then create artificial flood waves in the SAVA River, as far downstream as BRČKO (km 225). Initial ponding elevations of 295 and 290 m.ü.A. were considered. The effects of two different breach openings were studied: (a) a trapezoidal breach of 10 m bottom width; and (b) complete abrupt removal of the barriers.

(3) Breaching of DOLSKO GORGE Barrier. The deep narrow gorge just downstream of DOLSKO (km 832) on the SAVA River might conceivably be blocked by an artificial landslide. Such a barrier would impound 83 million m^3 of water at elevation 270 m.ü.A. and 325 million m^3 of water if carried to elevation 280. The extent of the pond is indicated on Plate 18. It must be admitted that this 500 m long by 10 to 20 m high barrier might be difficult to erect. However, subsequent breaching or failure of such a barrier would produce appreciable flood waves far downstream on the SAVA River. In order to determine the nature of those effects, trapezoidal breach openings of 100 and 200 m bottom widths, at elevation 265 m.ü.A., and initial ponding elevations of 280 and 270 m.ü.A., were considered.

d. Effects of MOSTE DAM Breaching Operations.

(1) General. The estimated effects of artificial flood waves on the SAVA River produced by breaching of MOSTE DAM are summarized in Table 7. Discharge hydrographs at key locations appear

on Plates 20 and 21. The artificial floods studied are designated as follows:

Artificial Flood No.	Width of Breach (m)	Depth of Breach (m)	Breach Elev.(m.ü.A.)	Pool Elev.(m.ü.A.)
1	10	5	509	514
2	"	8	"	517
3	"	14.5	"	523.5
4	"	5	518.5	"
5	20	"	"	"
6	"	10	513.5	"

(2) Artificial Flood No. 1 results from a 10 m wide by 5 m deep breach of MONTE DAM, considering the dam crest at 514 m.ü.A., the elevation of the first stage of construction. Discharge hydrographs at key locations and a sketch of the breach are shown on Plate 20. The peak discharge of 330 m^3/sec drops to about 100 m^3/sec (the capacity of the outlet conduit) in about 2 hours. The reservoir is emptied by the outlets in approximately 7 hours. The resulting rise in river stage is only 0.7 m at SMLEDNIK, 43 km below the dam and 0.3 m at ZAGREB, 204 km below the dam. As shown in Table 7, only slight increase in width and velocity of flow would be effected.

(3) Artificial Flood No. 2 would result from the same breach considered in Flood No. 1, assuming that the crest had been raised 3 m higher by temporary construction. The initial peak discharge would thus be increased from 330 to 590 m^3/sec. The downstream effects would be slightly greater than those of Flood No. 1, as shown on Plate 20 and in Table 7, but would still not appreciably differ from base flow conditions.

(4) Artificial Flood No. 3 would result from a breach with bottom width and elevation identical to Flood No. 1, but with the water surface at the ultimate dam crest elevation of 523.5 m.ü.A. The initial peak discharge would be 1545 m^3/sec and it would take over 3 hours for the discharge to drop to the outlet capacity (as shown on Plate 20). The resulting flood wave height above initial stage would be 1.9 m at SMLEDNIK, and 0.9 m at ZAGREB. Effects are summarized in Table 7. The comparison of depth, discharge, velocity to natural values is shown on the profiles of Plate 17.

(5) Artificial Flood No. 4 discharge hydrographs appear on Plate 21, and the summary of effects in Table 7. This flood illustrates the effect of reservoir storage upon the flood wave. The breach is 10 m wide by 5 m high, like Flood No. 1; however, the assumed water surface is 523.5, as compared to 514 m.ü.A. for that flood. As may be seen in Table 7, the duration of the resulting wave is about double that of Flood No. 1. This reflects the greater volume stored at the higher elevation.

(6) Artificial Flood No. 5 was included to determine the effect of width of breach upon the resulting flood wave. It results from a breach of 20 m bottom width, double that of Flood No. 4. As shown on

Plate 21 and in Table 7, the difference in discharge and other effects for those two breaches becomes progressively less as the waves progress downstream. At the dam, Flood No. 5 peak discharge is 540 m^3/sec, compared to 350 m^3/sec for Flood No. 4; at ZAGREB, crest discharges are 360 and 355 m^3/s, respectively. The other effects are practically identical.

(7) Artificial Flood No. 6 likewise may be compared to Flood No. 4. The assumed breach of 20 m bottom width and 10 m depth is twice as deep as that for Flood No. 4, and represents approximately the widest opening that might be fitted within the gorge at the damsite. A peak discharge of 1385 m^3/sec drops to the outlet capacity in about 3 hours. This discharge is nearly 4 times that of Flood No. 4 but about 90 percent as great as Flood No. 3. The downstream effects are appreciable as far downstream as ZAGREB. There, the discharge would be 440 m^3/sec for Flood No. 6 compared to 355 m^3/sec for Flood No. 4. The height of the wave at ZAGREB would be 0.7 m for the former and 0.4 m for the latter. The discharge hydrographs appear on Plate 21 and the summary of effects in Table 7.

c. Effects of LJUBLJANA Barrier Breaching Operations.

(1) General. The estimated effects of artificial flood waves on the SAVA River produced by breaching of the LJUBLJANA Barrier (km 852) are summarized in Table 7. Discharge hydrographs at the barrier and at STARA-GRADIŠKA (km 460) are shown as Plate 22. The artificial flood waves studied are designated as shown in the following tabulation:

Artificial Flood No.	Width of Breach (m)	Depth of Breach (m)	Breach Elev. (m.ü.A.)	Pool Elev. (m.ü.A.)
7	10	10	285	295
8	"	5	"	290
9	Complete removal	10	"	295
10	" "	5	"	290

(2) Artificial Flood No. 7 is the result of a 10 m wide by 10 m high trapezoidal breach of LJUBLJANA Barrier, considering the impounded water level to be 295 m.ü.A. The peak discharge would be 725 m^3/sec. Due to the large volume of stored water (655 million m^3), the duration of the wave would be nearly 30 days, as may be seen on the discharge hydrographs of Plate 22 and in the summary of Table 7. The wave height would decrease from nearly 2 m at LITIJA (39 km below the barrier) to about 0.5 m, 600 km below the barrier. In the lower reaches of the SAVA River below ZAGREB (Km 700), the crest of the wave would overtop the banks about 0.5 m. This would result in flooding of wide areas of low-lying land during the passage of the peak of the wave.

(3) Artificial Flood No. 8 results from a 10 m wide by 5 m deep breach at LJUBLJANA. The peak discharge would be only 225 m^3/sec. The volume of stored water at elevation 290 m.ü.A. is about one-tenth of that impounded at elevation 295 m.ü.A. The duration of the flood wave would be approximately one week, as compared to 30 days for Flood No. 7.

As shown on Plate 22 and in Table 7, the downstream effects would be much less than for that flood, and continuous overbank flooding could not be expected.

(4) Artificial Flood No. 9 assumes the complete demolition or abrupt removal of a barrier at LJUBLJANA. With the initial ponding level at 295 m.ü.A. behind the barrier, the resulting peak discharge would be approximately 2000 m^3/sec and the wave would last from 10 to 15 days. Appreciable increases in stage, velocity, discharge and width of flooding would result. For example, at STARA-GRADISKA, 392 km below LJUBLJANA, the stage would be increased about 3 m and the width of the water obstacle increased from 190 m to about 1 km. Reference is made to the summary of effects in Table 7, and to the depth, velocity, and discharge profiles of Plate 17.

(5) Artificial Flood No. 10 differs from that immediately preceding, in that the initial ponding level was taken to be 290 m.ü.A., 5 m lower than Flood No. 9. The peak discharge would be 500 m^3/sec at the barrier and the duration of the wave would be from 3 to 6 days. The height of the wave above initial stages would vary from about 1.5 m, 40 km below the barrier, less than 0.5 m, at locations more than 400 km below LJUBLJANA. The magnitude of the effects would be considerably less than Flood No. 9, but only slightly less than for Flood No. 7, although the duration would be only about one-eighth as long as the latter.

f. Effects of DOLSKO GORGE Barrier Breaching Operations.

(1) General. The estimated effects of artificial flood waves produced by assumed breaching or failure of a high barrier in DOLSKO GORGE (km 832) are summarized in Table 7. Discharge hydrographs at the barrier and at STARA-GRADISKA (km 460) are shown on Plate 23. The artificial flood waves considered are designated as follows:

Artificial Flood No.	Width of Breach (m)	Depth of Breach (m)	Breach Elev.(m.u.A.)	Pool Elev.(m.u.A.)
11	100	15	265	280
12	"	5	"	270
13	200	15	"	280
14	"	5	"	270

(2) Artificial Flood No. 11 would have a peak discharge at the breached barrier of 10,500 m^3/sec. A breach width of 100 m and depth of 15 m were assumed for this flood. The flow would rapidly decline to base flow in 1 to 2 days. At STARA-GRADISKA, approximately 370 km downstream, the increase above base flow would be only 1500 m^3/sec. Similarly, the height of the wave above initial stages would decrease from over 20 m in the gorge to less than 2 m in the lower reaches. However, the resulting flooding would inundate extensive areas in the flat plains below ZAGREB. Reference is made to Plate 23 for discharge hydrographs at the barrier and at STARA-GRADISKA and to Table 7 for summary of the estimated effects at key stations.

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(3) Artificial Flood No. 12 results from a 100 m wide breach, but with an assumed water surface of 270 m.ü.A., 10 m lower than for Flood No. 11. The peak discharge at the barrier would be only 1,950 m^3/sec, approximately one-fifth as great. The duration would still be only about 1 day, as shown on Plate 23. Table 7 shows that effects downstream would slightly exceed bankfull conditions.

(4) Artificial Flood No. 13 is the result of a 200 m wide and 15 m deep breach. The initial peak discharge of 20,300 m^3/sec is approximately twice that of Flood No. 11. The duration of discharge is about 1 day. Plate 23 and Table 7 indicate that the difference in discharges of Floods No. 11 and 13 become progressively smaller as the wave travels downstream, as was similarily observed in the case of Floods Nos. 4 and 5.

(5) Artificial Flood No. 14 effects are shown on the depth, velocity, and discharge profiles of Plate 17 as well as in the summary of effects Table 7. This flood would result from a 200 m wide by 5 m deep breach in the DOLSKO GORGE Barrier, assuming the water surface to be at a barrier crest elevation of 270 m.ü.A. A peak discharge of 3850 m^3/sec at the barrier would result in an increase of 350 m^3/sec above base flow at STARA-GRADISKA. The resulting peak conditions would slightly exceed those prevailing at bankfull conditions, and some significant localized inundation of low spots might be expected.

g. Comparison of Effects of Breaching Operations. Breaching of MOSTE DAM would result in slight increase of discharge, stage, and velocity above base flow conditions. Effects would be confined to the upper reaches of the SAVA River above ZAGREB (km 700). Breaching of a barrier at LJUBLJANA could produce significant flooding along the entire SAVA River, below ZAGREB. Breaching of a high barrier in DOLSKO GORGE would produce very high stages and flows in the gorge below that barrier, and appreciable flooding of lowlands below ZAGREB. Peak values for the various flood waves studied are summarized in Table 7. The relation of representative artificial waves to natural conditions is illustrated on Plate 17. Extracts of pertinent effects from Table 7 at selected key locations are presented below to facilitate comparison between the various artificial floods.

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Flood No.	Peak Values: Depth m	Width Flooded m	Overflow Height m	Mean Surface Velocity m/sec	Duration Days
(1) At LITIJA, Km 813					
(a) MOSTE DAM Breach					
1	2.7	160	Within banks	1.9	1/2
2	2.8	"	" "	"	"
3	3.4	165	" "	2.2	"
4	2.8	160	" "	1.9	1
5	2.9	"	" "	2.0	"
6	3.3	165	" "	2.2	3/4
(b) LJUBLJANA Barrier Breach					
7	4.3	170	Bankfull	2.6	25
8	2.9	160	Within banks	2.0	7
9	7.2	230	2.0	3.0	11
10	3.8	175	Within banks	2.4	4
(c) DOLSKO GORGE Barrier Breach					
11	(over 12)	(over 300)	(over 7)	(over 3)	2
12	6.2	200	1.0	3.0	1
13	(over 12)	(over 300)	(over 7)	(over 3)	"
14	8.2	250	3.0	3.0	"
(2) At ZAGREB, Km 700					
(a) MOSTE DAM Breach					
1	3.3	215	Within banks	1.0	3/4
2	3.4	"	" "	1.1	"
3	3.9	220	" "	1.4	"
4	3.4	215	" "	1.1	1-1/4
5	3.6	"	" "	1.2	1-1/2
6	3.7	220	" "	1.3	3/4
(b) LJUBLJANA Barrier Breach					
7	4.7	220	Bankfull	1.8	26
8	3.4	215	Within banks	1.1	7
9	6.4	240	1.5	2.5	12
10	4.1	220	Within banks	1.5	4
(c) DOLSKO GORGE Breach					
11	9.6	450	4.5	3.5	2
12	5.3	230	0.5	2.1	"
13	6.5	550/2000*	6.5	4.0	"
14	5.8	230	1.0	2.3	1
(3) At STARA GRADIŠKA, Km 460					
(a) MOSTE DAM Breach					
1-6			Insignificant effects		
(b) LJUBLJANA Barrier Breach					
7	9.1	210/1000*	0.5	1.1	28
8	6.7	195	Within banks	0.9	8
9	9.3	210/1000*	0.5	1.1	13
10	7.0	200	Within banks	0.9	6
(c) DOLSKO GORGE Barrier Breach					
11	10.4	220/2000*	1.5	1.2	3
12	7.5	200	Bankfull	0.9	2
13	10.7	230/2000*	2.0	1.2	3
14	7.7	200	Bankfull	0.9	2

*Levees intact; levees breached

4-04 STREAM FLOW VARIATIONS.

a. General. The studies in this paragraph pertain to the artificial flooding that might be produced along the SAVA River by release of water from the outlets of MOSTE DAM (km 904). These flow variations may be repeated to produce cyclic effects, dependent upon the replenishment of the reservoir storage. Reference is made to paragraph 2-10 and Exhibit B for description of the outlets and to Plate 7 for sketches of MOSTE DAM. Insufficient data were available to permit similar studies of the effect of releases from the other hydro-electric projects listed in Table 4.

b. Hydrologic Considerations. Reference is made to paragraph 4-03b for discussion of the influence of natural stream flow and initial reservoir pool elevation on artificial flooding effects. It is significant that the reservoir of MOSTE DAM can be refilled to full capacity in 5 days under mean water conditions.

c. Means of Creating Detrimental Flow Variations. Sudden opening of the control gates on the bottom outlet tunnel of MOSTE DAM (shown on Fig. 2 of Plate 7), would release an estimated 108 m^3/sec with the reservoir stage at 514 m.u.A. That corresponds to the elevation of the first stage of construction described in paragraph 2-10 and Exhibit B. The estimated discharge would be 125 m^3/sec with the water surface at 523.5 m.u.A., the elevation of the proposed ultimate dam crest. The discharge capacity of the power outlet is relatively small. Available information indicates that the possibilities of appreciably increasing regulated discharge by temporary by-passing, alteration, or dismantling of the outlet appurtenances are slight.

d. Effects of Detrimental Flow Variations.

(1) General. The effects of detrimental flow variations produced by releases from the outlets of MOSTE DAM are summarized on page 3 of Table 7. Representative discharge hydrographs are shown on Plate 24. Flow variations are designated for purposes of identification as follows:

Artificial Flood No.	Pool Elev. (m.u.A.)	Discharge (m^3/sec)	Storage (mil m^3)	Filling Time (days)
15	514	108	2.3	2
16	523.5	125	6.89	5

(2) Artificial Flood No. 15 is the result of discharge from the bottom outlet of MOSTE DAM, with the pool at 514 m.u.A., the elevation of the dam crest for the first stage of construction. The peak discharge of 108 m^3/sec would result in an increase of 49 m^3/sec over base flow at ZAGREB (km 700), as shown on Plate 24. River stages would be increased only about 0.2 m at that location, and would remain within banks throughout the downstream travel of the flood, as indicated in Table 7.

(3) Artificial Flood No. 16 involves the outlet discharge from MOSTE DAM with the pool at elevation 523.5, the proposed ultimate dam crest elevation. Peak discharge would be 125 m^3/sec. The effects would not be appreciably greater than those for Flood 15, as may be seen on Plate 24 and in Table 7. At ZAGREB the base flow discharge would be exceeded by 79 m^3/sec. The stage there would rise only 0.3 m and flow would remain within banks.

c. Comparison of Effects of Flow Variations. Reference is made to Table 7 for comparative summation of results. As may be seen in that table, the artificial flooding effects produced by outlet releases from MOSTE DAM are much smaller than those produced by breaching operations. Increase of reservoir stage does not appreciably increase effects of flow variations resulting from outlet discharges. A tabulation of comparative pertinent effects of the two flow variations studied, follows:

Flood No.	Peak Values: Depth	Width Flooded	Overflow height	Mean Surface Vel.	Duration
	m	m	m	m/sec	Days
(1) At OTOČE, Km 885					
15	2.5	80	Within banks	2.1	1/2
16	2.6	80	" "	2.2	3/4
(2) At LITIJA, Km 813					
15	2.6	160	Within banks	1.8	1/2
16	2.7	160	" "	1.9	1
(3) At ZAGREB, Km 700					
15	3.2	215	Within banks	1.0	3/4
16	3.3	215	" "	1.0	1-1/4

4-05 ARTIFICIAL FLOODING POTENTIALITIES OF CANALS AND LAKES.

a. Canals. Since there are no navigation canals in the area, artificial flooding can not be produced from that source. Blocking of drainage canals coupled with breaching of dikes and destruction of drainage pumps could create "Drainage Obstacles," as described in paragraph 4-02.

b. Lakes. Approximately 10 million m^3 could be stored in the BOHINJSKO JEZERO, assuming that the lake level could be raised and retained at 3 m above normal. Similarly, about one-half million m^3 could be stored in LAKE BLED, at 0.4 m above normal stage. These stages approximate the maximum levels attained during the period of record 1902-1946 for the former and 1896-1946 for the latter. (See Reference 27). Insufficient information is available to determine the feasibility of such water retention in these headwater lakes of the SAVA River Basin, or the rate of discharge if the water were suddenly released. However, it might be estimated that the discharge would not exceed 150 m^3/sec. That would not be sufficient to create appreciable flow variations. The volume of water so stored is small compared to natural flow volumes in the SAVA River but could supplement other sources of water supply for stillwater barriers, described in paragraph 4-02.

4-06 SUMMARY.

The artificial flooding potentialities of the SAVA River described in preceding paragraphs 4-01 to 4-05 are herein summarized:

a. Temporary damming at suitable bridge openings or other constrictions would create still-water obstacles of variable sizes. Resulting flooding would be slight in reaches above ZAGREB (km 700). Inundated areas 18 to 60 km long, 2 to 10 km wide, and averaging over 1 meter deep could be created at LJUBLJANA (km 852) or at several locations downstream from ZAGREB. Blocking of normal drainage facilities would create marshy drainage obstacles covering large areas in the LJUBLJANA Basin and in the lower reaches of the SAVA River. The inundation effects are summarized in Table 6 and described in paragraph 4-02. Locations and extent of still-water barriers are indicated on Plate 18.

b. Breaching of the MOSTE DAM (Km 904) would create artificial flood waves in the SAVA River. Due to the limited storage capacity of that reservoir and to the narrow width of the gorge at the damsite, wave heights would not be dangerously large. Reference is made to paragraph 4-03 for detailed discussion and to Table 7 for summation of effects. A tabulation of the range of pertinent effects for the floods studied follows:

Item	Unit	OTOČE (Km 885)	ZAGREB (Km 700)
Amplitude of wave	m	0.7 - 1.4	0.3 - 0.9
Duration of wave	days	1/4 - 1	3/4 - 1-1/2
Rate of Rise	m/hr	0.35 - 0.7	0.03 - 0.1
Time of Crest	hr	3	28 - 32
Overbank depth	m	Within banks	Within banks
Width flooded	m	85 - 130	215 - 220
Max. mean surface velocity	m/sec	2.3 - 2.5	1.0 - 1.4

c. Breaching of a temporary barrier at LJUBLJANA (Km 852) would create significant major artificial flood waves in the SAVA River. Effects would be appreciable as far downstream as BRCKO (Km 225). See paragraph 4-03 for discussion and Table 7 for summary of effects. A tabulation of the range of these effects follows:

Item	Unit	LITIJA (Km 813)	STARA-GRADIŠKA (Km 460)
Amplitude of wave	m	0.5 - 4.8	0.3 - 2.9
Duration of wave	days	4 - 25	6 - 28
Rate of Rise	m/hr	0.04 - 0.5	0.005 - 0.04
Time of Crest	hr	12 - 14	108 - 125
Overbank depth	m	Within banks-2.0	Within banks-0.5
Width flooded	m	160 - 230	195 - 1000
Max. mean surface velocity	m/sec	2.4 - 3.0	0.9 - 1.1

d. Breaching of a temporary high dam or barrier erected in DOLSKO GORGE (Km 832) would also create major artificial flood waves in

the SAVA River. The magnitude of effects is largely dependent upon the height of the barrier. For heights of barrier in excess of about 15 m, appreciable effects would be felt as far downstream as BRCKO (Km 225). Discussion is contained in paragraph 4-03 and summary of effects is included in Table 7. A tabulation of the range of effects follows:

Item	Unit	LITIJA (Km 813)	STARA-GRADISKA (Km 460)
Amplitude of wave	m	3.8-(over 9.5)	1.1 - 4.3
Duration of wave	days	1	2 - 3
Rate of Rise	m/hr	0.5-(over 2)	0.02 - 0.08
Time of Crest	hr	6 - 9	96 - 105
Overbank depth	m	1.0-(over 7)	Bankfull - 2.0
Width flooded	m	200-(over 300)	200 - 2000
Max. meansurface vel.	m/sec	3.0-(over 3)	0.9 - 1.2

e. Flow variations of small magnitude could be produced in the upper reaches of the SAVA River by opening the controlled outlets of MOSTE DAM (Km 904). Cyclic variations could be repeated at 2 to 5 day intervals. Reference is made to paragraph 4-04 and Table 7. A tabulation of effects follows:

Item	Unit	OTOČE (Km 885)	ZAGREB (Km 700)
Amplitude of rise	m	0.5 - 0.6	0.2 - 0.3
Duration of rise	days	1/2 - 1	3/4 - 1-1/4
Rate of Rise	m/hr	0.1	0.02
Time of Crest	hr	6 - 9	31 - 36
Overbank depth	m	Within banks	Within banks
Width flooded	m	80	215
Max. mean surface vel.	m/sec	2.1 - 2.2	1.0

f. Demolition or failure of the temporary dams used for still-water barriers discussed in paragraph 4-02 would produce flood waves of short duration and magnitude. Significant effects would not be produced except in the reaches several kilometers below the destroyed barrier. Failure of such temporary dams might be caused by flow overtopping the structure. Therefore, adequate relief spillways or outlets should be provided.

g. The effects of artificial flood waves or flow variations depend largely upon the base flow (i.e., the flow in the stream before arrival of the flood). The studies presented in this report were based upon an assumed base flow approximating mean water conditions. The following tabulation illustrates the comparative effects produced by Flood No. 7 at ZAGREB (Km 700) with base flows of 250 m^3/sec (mean water flow as shown in Table 7) and 1000 m^3/sec:

Item	Unit	ZAGREB		Source
(1) Base Flow	m^3/sec	250	1000	Assumed values
(2) Discharge Increase	m^3/sec	530	530	Table 7
(3) Crest Discharge	m^3/sec	780	1530	(2) plus (3)
(4) Initial Gage Height	cm	35	255	From Plate 15 for (1)
(5) Crest Gage Height	cm	200	355	From Plate 15 for (2)
(6) Stage Increase	m	1.7	1.0	(4) minus (5)
(7) Initial Mean Surface Vel.	m/sec	0.3	2.1	From Plate 15 for (4)
(8) Crest MeanSurface Vel.	m/sec	1.8	2.5	From Plate 15 for (5)
(9) Velocity Increase	m/sec	1.0	0.4	(7) minus (8)

SECTION V
EFFECT ON MILITARY OPERATIONS

5-01 GENERAL.

The purpose of this section is to assist military planning personnel in estimating the relative value and effect of artificial floods upon associated military factors such as bridging, ferrying, and trafficability. The effects of artificial floods upon military operations may vary greatly, depending on hydrologic and weather conditions, the tactical and logistical situation, and the type of equipment involved. Reference is made to Section IV for discussion of the hydraulic features associated with artificial flooding.

5-02 CHARACTERISTICS OF MILITARY BRIDGING.

a. The loading capacities of standard U. S. Army floating bridging, for conditions classified as "Safe, Caution, and Risk Crossings," for various current velocities are tabulated in Table 8. Included are the current velocities which are presumed to destroy the bridge in place with no load, the values ranging from 9 to 16 feet per second (i.e., about 2.7 to 4.9 m/sec). Table 8 is primarily based on data contained in References 28 and 29.

b. It should be noted that the velocities shown in Table 8 represent general averages. The ability of floating bridges to withstand current velocities depends upon numerous variable factors, such as special provisions for securing the bridge, the rate of change in river stage, direction and variability of current, debris carried by the stream and other considerations. Standard bridging has been successfully utilized under conditions more severe than indicated in Table 8, and has failed under apparently less critical velocity.

5-03 EFFECTS OF ARTIFICIAL FLOODING DURING ACTUAL CROSSING OPERATIONS.

No information is available regarding details of actual military river crossings of the streams in the SAVA River Basin, nor of the observed influence of artificial flooding upon such operations.

5-04 EFFECT OF STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. Reference is made to paragraphs 4-02 and 4-06 for discussion of the hydraulic features associated with formation and augmentation of water obstacles by means of temporary damming operations or by disruption of normal drainage.

b. Bridging and ferrying operations within the backwater reaches upstream from the temporary dams would be hindered by reason of the resulting greater width and depth of crossing, indicated in Table 6 and on Plate 18. Approach trafficability would be reduced by the shallow overbank flooding, and the increased stream depths would hinder fording of the affected reaches of the river. Since the

resulting increased water obstacles would not be continuous along the streams (as illustrated on Plate 18), still-water barriers must be combined with other natural obstacles and with tactical operations in order to channelize military action.

c. Shallow inundation, even of short duration, over the wide flat LJUBLJANA plain would probably reduce overland trafficability long after the end of such flooding. That plain is naturally marshy and any disruption of the extensive artificial drainage facilities would quickly cause it to revert to that state. The main roads and railroads are located on embankments and would probably be unaffected except in isolated low-lying spots or where culverts or bridges were demolished.

d. Any inundation of the low-lying land along the lower reaches of the SAVA River, such as that shown on Plate 18 as created by still-water barriers, would reduce overland trafficability for extended periods. That region has inadequate drainage and is naturally inundated or marshy for most of the year as a result of natural floods. Consequently, very few roads or railroads have been built in those areas.

e. Continuous military support of the temporary dam installations would be necessary to prevent their destruction by enemy air or ground action. Destruction of a temporary dam would release a flood wave of short duration that would temporarily hinder crossing operations below the structure and which might cause progressive failure of other downstream structures.

f. Breaching of levees would be necessary in some cases; while, in others, blocking of culverts and drainage outlets would be required in addition to temporary damming operations in order to create effective still-water barriers and drainage obstacles.

5-05 EFFECT OF MAJOR FLOOD WAVES.

a. Reference is made to paragraphs 4-03 and 4-06 for discussion of the hydraulic features associated with creation of major flood waves by means of breaching of MOSTE DAM and of temporary barriers at LJUBLJANA and DOLSKO GORGE.

b. Breaching of MOSTE DAM would create artificial flood waves. However, the associated damage to bridges or dams would probably not be large. The temporary increased river stage and velocity would not be sufficiently large to seriously interfere with crossing operations, except for less than 20 km below the dam. While little overbank flooding would be created, velocities in that reach probably could become swift enough to hinder bridging operations.

c. Breaching of MOSTE DAM or of other hydro-electric structures would seriously disrupt the electrical power supply of important industrial and urban areas such as the JESENICE steel mills.

d. Breaching of a temporary dam or barrier on the LJUBLJANA River could create artificial flood waves that would interfere with stream crossing operations and endanger equipage and floating bridges along the SAVA River nearly to ZAGREB. Insufficient data are available regarding structural features of existing bridges and dams to permit estimate of the degree of destruction. The flood wave would reduce trafficability over the extensive flat areas along the lower reaches of the SAVA River downstream of ZAGREB.

e. Breaching of a high temporary barrier across the SAVA River near the upstream entrance to the DOLSKO GORGE would produce artificial flood waves of considerable effectiveness. The resulting stages and velocities would be extremely high in the gorge and would probably destroy or damage existing bridges and seriously interfere with any crossing operations and possibly hinder rail and highway traffic through the 75 km long gorge. Below ZAGREB, overbank flooding would be extensive (if levees are also breached) and trafficability would be reduced. Erection of a high barrier might be difficult. Also, premature failure or destruction of the temporary barrier might occur, releasing a flood wave earlier than desirable.

f. Breaching of levees and destruction of drainage facilities might be necessary in some cases in order to fully exploit the maximum possible effectiveness of artificial flood waves.

g. Military support of the permanent or temporary dam installations would be necessary to prevent their destruction by enemy air or ground action. Such destruction would prematurely release flood waves that could hinder action by our forces below the structure. Deliberate demolition of dams or barriers would prevent their use by the enemy in producing detrimental major flood waves or flow variations during a later critical period.

5-06 EFFECT OF FLOW VARIATIONS.

a. Reference is made to paragraphs 4-04 and 4-06 for discussion of the possible detrimental flow variations that could be created on the SAVA River by means of regulated discharge from MOSTE DAM. The resulting flow conditions are summarised in Table 7.

b. Release of water from the outlets of MOSTE DAM or of other hydro-electric projects would produce flow variations in the SAVA River downstream of the structures. The magnitude would not be large enough to interfere seriously with military operations. However, the increased stage and velocity would inconvenience floating bridging or crossing operations, especially if cyclic releases are effected.

c. Water stored in the reservoirs of MOSTE DAM and other hydro-electric projects could be released to provide a supplementary supply of water for still-water barriers previously discussed in paragraphs 4-04 and 5-04. Similar use might be made of BOHINJSKO JEZERO and LAKE BLED storage, as described in paragraph 4-05.

d. Destruction of the outlets and machinery of the hydro-electric dams would seriously disrupt the electric power supply of the JESENICE steel mills and other industrial and urban areas. Opening of the outlets and destruction of the regulating gates and valves to drain the reservoirs would have a similar effect.

5-07 EFFECTS RELATED TO OTHER BASINS.

a. Artificial flooding along the SAVA River could be coordinated with similar operations on other nearby river basins to create simultaneous or progressive water obstacles affecting military action. Specific reference is made to studies on the DRAVA River Basin and rivers of the NORTH ITALIAN PLAIN currently being undertaken by this office.

b. Retention of water in the reservoirs of the SAVA River Basin during drought periods could reduce navigable stages on the SAVA River and in the IRON GAP reach of the DANUBE River. The storage capacities of the existing reservoirs are probably insufficient to exert an appreciable effect. However, upon construction of the proposed reservoirs in this basin, as described in Exhibit A, the effectiveness of such operations would be increased.

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TABLE I
EQUIVALENT ENGLISH-METRIC TERMS

To reduce A to B, multiply A by F. To reduce B to A, multiply B by G

Unit A	Factor F	Factor G	Unit B
	LENGTH		
Miles	1.60935	.62137	Kilometers
Meters	3.2808	.30480	Feet
Meters	39.370	.025400	Inches
	AREA		
Square Miles	2.590	.3861	Square Kilometer
Square Miles	259.000	.0038610	Hectares
Hectares	2.47104	.40469	Acres
Acres	4046.9	.00024710	Square Meters
	VOLUME		
Cubic Meters	35.3145	.028317	Cubic Feet
Cubic Feet	28.317	.035314	Liters
Acre-feet	43560.	.000022957	Cubic Feet
Acre-feet	1233.5	.00081071	Cubic Meters
	DISCHARGE		
Cubic feet per second	1.9835	.50417	Acre-feet per 24
Cubic meters per second	35.3145	.028317	Cubic-feet per
	VELOCITY		
Miles per hour	1.60935	.62137	Kilometers per
Miles per hour	1.4667	.68182	Feet per second
Meters per second	3.2808	.30480	Feet per second
Meters per second	2.2369	.44704	Miles per hour
Meters per second	3.600	.2778	Kilometers per
Feet per second	1.097	.9113	Kilometers per
	WEIGHT		
Tons (metric)	1.102	.9072	Tons (short)
Tons (long)	1.016	.9842	Tons (metric)
Tons (metric)	2205.	.0004536	Pounds (avoirdu
Tons (metric)	1000.	.001	Kilograms

Tab

TABLE 2
HYDROLOGIC TERMS AND ABBREVIATIONS
(In conformance with German practice)

Non-Tidal Stage	High-Tide Stage	Low-Tide Stage	Rate of Discharge (m^3/sec)	Discharge per Unit area (1/sec-km^2)	Definition
HHW	HHThw	HHTnw	HHQ	HHq	Highest value ever known or observed
HW	HThw	HTnw	HQ	Hq	Highest value observed during a stated period of time
MHW	MHThw	MHTnw	MHQ	MHq	The mean high value during a stated period, derived by averaging the highest values of each unit time element (i.e. MHW 1926/35 is average of the 10 yearly peak stages)
MW	MThw	MTnw	MQ	Mq	The mean (arithmetical average) of all observations during a stated time period
MNW	MNThw	MNTnw	MNQ	MNq	The mean low value during a stated period, derived by averaging the lowest values of each unit time element (MNW 1926/35 is the average of the 10 yearly lowest stages)
NW	NThw	NTnw	NQ	Nq	Lowest value observed during a stated period of time
NNW	NNThw	NNTnw	NNQ	NNq	Lowest value ever known or observed

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TABLE 3

SUMMARY OF GAGE DATA

Station Number	Name of Gaging Station: Jugoslavian	Name of Gaging Station: Austrian	U.T.M. Grid Coordinates	River Km	Drainage Area Km²	Approximate Top of Bank M.ü.A. (Meters above Adriatic Sea)	Approximate Stream bed M.ü.A. (Meters above Adriatic Sea)	Gage Zero (1)	Minimum Date (1)	Minimum NNW CM(1)	Minimum NNQ M³/sec(3)	Period
	SAVA DOLINKA (WURZNER SAVE) RIVER											
1	JAVORNIK	(JAUERBURG)	VM 295415	908	270.4	525	523	523.401	18-20 Mar 1909	44	0.3	1907-1
2	BLED BRIDGE	(VELDESBRÜCKE)	394359	898	898.1	433	428.2	429.000	15-20 Mar 1909	-24	8	1903-1
	BOHINJSKO JEZERO (WOCHEINER SEE) (i.e. LAKE)											
3	SVETI DUH	(HEILIGEN GEIST KIRCHE)	126256	918	57.8	530	-	525.397 525.40 *	24-25 Feb 1909 18 Feb-10 Mar 29*	6 -5*	-	1902-1
	SAVA BOHINJKA (WOCHEINER SAVE) RIVER											
4		(STIEGE)	-	909	323.3	-	475.7	475.659	30-31 Dec 1910	-26	0.4	1903-1
	BLEJSKO JEZERO (VELDESER SEE) (i.e. LAKE BLED)											
5	BLED	(VELDES)	310350	-	9.3	-	-	475.665 475.67 *	4 Feb 1896 4 Feb 1896*	-6 -6*	0.5	1903-1
	LJUBLJANA (LAIBACH) RIVER											
6	VRHNIKA	(OBERLAIBACH)	VL 458909	870	1241.7	290	285.7	287.807	3 Aug 1872	-6	17	1899-1
7	PODPEČ		550917	865	-	290	285.0	285.667	15 Sep 1911	-16	-	1903-1
8	LJUBLJANA	(LAIBACH)	618995	852	1072.9	290	284.8	287.837	15 Oct 1890	-238	17	1899-1
9		(OBERKASCHAL)	VM 688000	840	-	270	265.6	-	12-18 Feb 1911	170	-	1909-1

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TABLE 3

SUMMARY OF GAGE DATA

	U.T.M. Grid Coordinates	River Km	Drainage Area Km²	Approximate Top of Bank M.U.A. (Meters above Adriatic Sea)	Approximate Stream bed	Gage Zero (1)	Minimum Date (1)	Minimum NNW CM(1)	Minimum NNQ M³/sec(3)	Mean Period	Mean NW CM	Mean MQ(3) M³/sec	Maximum Date	Maximum HHW CM	Maximum HHQ M³/sec(3)
	VH 295415	908	270.4	525	523	523.401	18-20 Mar 1909	44	0.3	1907-1912	72	11-18	10 Dec 1910	160	200
	334353	898	896.1	433	428.2	429.000	15-20 Mar 1909	-24	8	1903-1911	18	30-50	16 Jun 1901	245	450
EL)	120256	918	57.8	530	-	525.397 525.40 *	24-25 Feb 1909 18 Feb-10 Mar 29*	6 -5*	-	1902-1911	42	5-8	20 Nov 1906 30 Nov 1933*	175 374*	-
	-	969	323.3	-	475.7	476.639	30-31 Dec 1910	26	0.4	1903-1912	53	3-5	9 Dec 1910	245	-
ALMO)	310350	-	9.3	-	-	475.665 475.67 *	4 Feb 1896 4 Feb 1896*	-6 -6*	0.5	1903-1912	6	-	19 Jun 1907 31 Oct 1926*	40 50*	-
	VL 458909	870	1241.7	290	285.7	287.807	3 Aug 1872	-166	12	1899-1908	-35	-	10 Nov 1851	340	-
	550917	863	-	290	285.0	285.667	15 Sep 1911	-16	-	1903-1912	105	-	22 Dec 1909	400	-
	618995	854	1072.9	290	284.8	287.837	15 Oct 1890	-238	17	1899-1908	-139	24	29 Oct 1895	146	205
	VH 664004	840	-	270	265.6	-	12-18 Feb 1911	170	-	1909-1911	233	-	15 Jun 1911	370	-

Prepared by Military Hydrology R&D Branch
Washington Dist., Corps of Engineers

NOTES:

* Based on 1944 "Godišnjak o Vodostajima, 1943-1944 Godine"

(1) Unless otherwise noted, Data for stations No. 1-25, incl., are based on 1912 "Jahrbuch des K.K. Hydrographischen Zentralbureaus"; stations No. 26-45, incl., on "Podaci, za Regulacije Save i Melioraciju Posavlja," 1919

(2) Data from 1941 "Monografia Geografico-Militare sui Territori d'Occupazione Croazia e Bosnia"

(3) Estimated Discharge - See para. 3-05

(4) Zone 34 Grid

(5) Danube Grid

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TABLE 3

SUMMARY OF GAGE DATA (Continued)

Station Number	Name of Gaging Station: Jugoslavian	Name of Gaging Station: Austrian	U.T.M. Grid Coordinates	River Km	Drainage Area Km²	Approximate Top of Bank M.ü.A. (Meters above Adriatic Sea)	Approximate Stream Bed M.ü.A. (Meters above Adriatic Sea)	Gage Zero (1)	Minimum: Date (1)	Minimum: NNW CM(1)	Minimum: NNQ M³/sec(3)	Peri[od]
	SAVA (SAVE) RIVER											
10	RADOVLJICA	(RADMANNSDORF)	VM 358324	893	887.9	417	384.3	385.510 409.12 *	1-2 Jan 1907 1929-1932 *	-37 -40*	8	1898-1[illegible]
11	OKROGLO	(OKROGLO)	336303	888	-	395	376	-	21-25 Feb 1909	19	-	1909-1[illegible]
12	OTOČE	(OTOČE)	413292	885	-	387	370	-	24-25 Feb 1909	29	-	1909-1[illegible]
13	KRANJ	(KRAINBURG)	502209	871	1229.7	347.5	345	347.066 348.06 *	31 Jan-1 Feb 09 24 Sep 1944*	-196 -18[illegible]*	13	1899-1[illegible]
14	SMLEDNIK	(FLÖDNIG)	558127	861	1523.8	330	320	320.244	12 Aug 1905	-12	15	1903-1[illegible]
15	TACEN	(TAZEN)	595073	852	2201.8	300	296	298.040 297.96 *	20 Feb-2 May 09 20 Feb 1942*	-196 -344*	20	1899-19[illegible]
16	ČRNUČE	(TSCHERNUTSCH)	630055	847	2274.4	290	283.4	285.244	15-28 Feb 1909	-12	21	1898-19[illegible]
17	SV. JAKOB	(ST. JAKOB)	675035	842	2301.6	275	272	273.284	14 Mar 189[illegible]	-67	33	1899-19[illegible]
18	SLAVNICA	(SIAPNICA)	760035	830	4902.6	262	253	253.635	13-15 Dec 1899	-30	41	1899-19[illegible]
19	LITIJA	(LITTAI)	865006	813	4967.3	235	230	231.716 231.72 *	25 Sep 1850 1 Oct 1922*	-26 -26*	41	1902-19[illegible]
20	ZAGORJE	(SAGOR)	993075	798	5153.7	220	207.1	211.650	28 Feb-1 Mar 09	9	42	1902-19[illegible]
21	RADEČE	(RATSCHACH)	WM 140020	779	7235.1	-	182.5	185.046 185.16 *	10-11 Nov 1908 1921-1932 *	-12 -21*	42	1909-19[illegible]
22	SEVNICA	(LICHTENWALD)	WL 240947	763	7668.1	-	166.3	168.623	25 Oct 1908	-19	42	1902-19[illegible]
23	KRŠKO	(GURKFELD)	377900	747	7898.5	-	154.6	156.422 156.44 *	3 Sep 1853 21 Sep 1944*	-36 -191	43	1899-19[illegible]
24	BREŽICE	(RANN)	460830	735	7988.3	-	139.9	141.918	23 May 1870	-55	49	1893-19[illegible] 1928-19[illegible]

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SECURITY INFORMATION

TABLE 3

SUMMARY OF GAGE DATA (Continued)

U.T.M. Grid Coordinates	River Km	Drainage Area Km²	Approximate Top of Bank M.U.A. (Meters above Adriatic Sea)	Approximate Stream Bed M.U.A. (Meters above Adriatic Sea)	Gage Zero (1)	Minimum Date (1)	Minimum NNW CM(1)	Minimum NNQ M³/sec(3)	Mean Period	Mean MW CM	Mean MQ(3) M³/sec	Maximum Date	Maximum HHW CM	Maximum HHQ M³/sec(3)
VH 358324	893	887.9	417	384.3	385.510 409.12 *	1-2 Jan 1907 1929-1932 *	-37 -40*	8	1898-1907	18	35-55	26 June 1900 29 Nov 1923 *	276 305*	450
396303	888	-	395	376	-	21-25 Feb 1909	19	-	1909-1912	83	40-70	10 Dec 1910	310	450
413292	885	-	387	370	-	24-25 Feb 1909	29	-	1909-1912	64	40-70	10 Dec 1910	216	450
502249	871	1229.7	347.5	345	347.066 348.06*	31 Jan-1 Feb 09 24 Sep 1944*	-196 -188*	13	1899-1908	-26	44-72	10 Dec 1910 30 Oct 1926*	210 400*	450
558127	861	1523.8	330	320	320.244	12 Aug 1905	-12	15	1903-1912	32	50-85	17 Nov 1901	280	460
595073	852	2201.8	300	296	298.040 297.96 *	20 Feb-2 May 09 20 Feb 1942*	-196 -344*	20	1899-1908	-40	75-120	20 Oct 1896 30 Oct 1926*	380 180*	800
630035	847	2274.4	290	283.4	285.244	15-28 Feb 1909	-12	21	1898-1907	50	77-123	20 Oct 1896	589	850
675035	842	2341.6	275	272	273.284	14 Mar 189-	-67	33	1899-1908	83	78-125	18 Oct 1907	405	850
780035	830	4962.6	262	253	253.635	13-15 Dec 1899	-30	41	1899-1908	81	150-250	16 Nov 1901	350	1060
865000	813	4967.3	235	230	231.716 231.72 *	25 Sep 1850 1 Oct 1922*	-26 -26*	41	1902-1911	68	150-250	4 Oct 1851	601	1340
993075	798	5143.7	220	207.1	211.650	28 Feb-1 Mar 09	9	42	1902-1911	106	150-260	16 Nov 1901	665	1500
WH 140020	779	7435.1	-	182.5	185.046 185.18 *	10-11 Nov 1908 1921-1932 *	-12 -21*	42	1909-1912	71	175-280	21 Dec 1909 23 Nov 1933*	530 725*	1560
WL 240947	765	7688.1	-	166.3	168.623	25 Oct 1908	-19	42	1902-1911	81	175-285	16 Nov 1901	620	1570
377900	747	7893.5	-	154.6	156.422 156.44 *	3 Sep 1853 21 Sep 1944*	-36 -191	43	1899-1908	39	184-280	6 May 1851 23 Sep 1933*	549 745*	1570
460830	735	7988.3	-	139.9	141.918	23 May 1870	-55	49	1893-1902 1928-1937(2)	92 47.2	184-280	24 Sep 1933(2)	510(2)	1600

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NOTES: See Page 1, Table 3

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TABLE 3

SUMMARY OF GAGE DATA (Continued)

Station Number	Name of Gaging Station: Jugoslavian	Name of Gaging Station: Austrian	U.T.M. Grid Coordinates	River Km	Drainage Area Km^2	Approximate Top of Bank M.a.A. (Meters above Adriatic Sea)	Approximate Stream Bed M.a.A. (Meters above Adriatic Sea)	Gage Zero (1)	Minimum: Date (1)	Minimum: HNW GN(1)	Minimum: NNQ M^3/sec(3)
	SAVA (SAVE) RIVER (Continued)										
25	ČATEŽ	(ČATEŽ)	WL 470025	732	9951.2	-	134.0	139.967 140.55 *	24 Oct 1909 9 Oct 1929*	11 -48*	59
26	PODSUSED		648740	713	12,200	-	120.6	122.66 120.48 *	1896-1905 21 Oct 1921*	18 -65*	66
27	ZAGREB	(AGRAM)	744708	700	12,500	-	109.6	112.27 112.26 *	1896-1905 1928-1939*	-118 -160*	67
28	RUGVICA		958668	663	12,800	-	93.0	95.71	1896-1905	-61	84
29	DUBRUČAK		XL 050555	636	-	-	90.1	94.911	1896-1905	-196	-
30	GALDOVO		070380	595	-	-	87.5	91.528 91.47 *	1896-1905 1887 *	-214* -214	-
31	GUŠĆE		240310	568	24,300 (km 571)	-	83.6	89.099 89.04 *	1896-1905 15-18 Sep 1942*	-102 -67*	101
32	JASENOVAC		480150	508	-	-	83.5	86.750 86.82 *	1896-1905 22 Oct 1921*	-11 -34*	-
33	STARA-GRADIŠKA		770020	460	39,500	-	82.0	85.403 85.40 *	1896-1905 12-18 Sep 1942*	-26.6 0*	139
34	MAČKOVAC		830035	447	39,800	-	81.0	-	-	-	-
35	KOBAŠ		YK 155978	396	-	-	78.0	82.564 82.60 *	1896-1905 5 Oct 1920*	34 2*	-
36	DUBOVAC		255923	385	48,200	-	77.5	-	-	-	-
37	BROD		BR 650045(4)	365	-	-	77.3	81.804 81.80 *	1896-1905 3 Oct 1865*	-18 -19*	-

TABLE 3

SUMMARY OF GAGE DATA (Continued)

U.T.M. Grid Coordinates	River Km	Drainage Area Km²	Approximate Top of Bank M.A.A. (Meters above Adriatic Sea)	Approximate Stream Bed M.A.A. (Meters above Adriatic Sea)	Gage Zero (1)	Minimum Date (1)	Minimum MNW CM(1)	Minimum MNQ M³/sec(3)	Mean Period	Mean MW CM	Mean MQ(3) M³/sec	Maximum Date	Maximum HHW CM	Maximum M³/sec(3)
XL 970823	732	9951.2	-	139.0	139.967 140.55 *	24 Oct 1909 9 Oct 1929*	11 -48*	59	1907-1912	121	200-300	22 Dec 1901 23 Sep 1938*	485 560*	1740
648740	713	12,200	-	120.6	122.66 120.48 *	1896-1905 21 Oct 1921*	18 -65*	66	1928-1937(2)	98.7(2)	230-330	18 Oct 1895*	555*	1890
744708	700	12,500	-	109.6	112.27 112.26 *	1896-1905 1928-1939*	-118 -160*	67	1928-1937(2)	-3.5(2)	230-330	24 Sep 1933(2)	458(2)	1880
958668	663	12,800	-	93.0	95.71	1896-1905	-61	84	1928-1937(2)	141.3(2)	230-330	1896-1905	878	1920
XL 050555	636	-	-	90.1	94.911	1896-1905	-196	-	1896-1905 1928-1937(2)	103 65.5	230-330	1896-1905	882	1920
070380	595	-	-	87.5	91.528 91.47 *	1896-1905 1887 *	-214* -214	-	1928-1937(2)	206.3(2)	230-330	1896-1905 1887 *	892 890*	1920
240310	560	24,300 (km 571)	-	83.6	89.099 89.04 *	1896-1905 15-18 Sep 1942*	-102 -67*	101	1896-1905	335	330-400	1896-1905 9 Aug 1937*	904 920*	2420
480150	508	-	-	83.5	86.750 86.82 *	1896-1905 22 Oct 1921*	-11 -34*	-	1896-1905	382	500-610	1896-1905 16 Nov 1935*	[illegible] [illegible]	2700
770020	460	39,500	-	82.0	85.403 85.40 *	1896-1905 12-18 Sep 1942*	-26.6 0*	139	1896-1905	350	530-650	1896-1905 16 Jul 1944*	840 848*	2920
830035	447	39,800	-	81.0	-	-	-	-	-	-	-	-	-	-
YL 155976	396	-	-	78.0	82.564 82.66 *	1896-1905 5 Oct 1920*	34 2*	-	1896-1905	399	620-780	1896-1905	958	3180
355923	385	48,200	-	77.5	-	-	-	-	-	-	-	-	-	-
[illegible](4)	[illegible]	-	-	77.3	81.804 81.80 *	1896-1905 3 Oct 1865*	-18 -19*	-	1896-1905	344	650-810	1896-1905 16 Apr 1932*	843 864*	3220

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NOTES: See Page 1, Table 3

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TABLE 3

SUMMARY OF GAGE DATA (Continued)

Station Number	Name of Gaging Station: Jugoslavian	Name of Gaging Station: Austrian	U.T.M. Grid Coordinates	River Km	Drainage Area Km²	Approximate Top of Bank M.u.A. (Meters above Adriatic Sea)	Approximate Stream Bed M.u.A. (Meters above Adriatic Sea)	Gage Zero (1)	Minimum: Date (1)	Minimum: NNW CM(1)	Minimum: NNQ M³/sec(3)	Perio
	SAVA (SAVE) RIVER (Continued)											
38	ŠAMAC		CQ 0393(4)	308	-	-	76.5	80.639 80.64 *	1896-1905 22, 23 Oct 1921*	0 -59*	-	1896-19
39	ŽUPANJE		1893(4)	263	61,000 (at Km 257)	-	72.5	76.361 76.24 *	1896-1905 23 Jul 1921*	18 -26*	183	1896-19
40	BRČKO		2571(4)	225	63,000	-	72.2	76.620 76.62 *	1896-1905 1 Sep 1943*	-53.5 -68*	186	1896-19
41	RAČA		X 360375(5)	177	-	-	79.0	74.682	1896-1905	80	-	1896-19
42	BOSUT		400420(5)	160	-	-	65.8	72.636	Prior to 1911	1		5 yrs prior to
43	MITROVICA	(MITROWITZ)	425603(5)	136	87,500	-	67.2	72.226 72.22 *	Prior to 1911 1890*	14 14*	250	1922-19
44	SEMLIN		Y 152233(5)	2.5	-	-	-	-	-			
45	BEOGRAD or BELGRADE		180250(5)	0	95,400	-	-	68.23 *	28 Oct 1921*	130*	-	-

NOTES:

TABLE 3

SUMMARY OF GAGE DATA (Continued)

U.T.M. Grid Coordinates	River Km	Drainage Area Km^2	Approximate Top of Bank	Approximate Stream Bed	Gage Zero (1)	Minimum			Mean			Maximum		
			M.W.A. (Meters above Adriatic Sea)			Date (1)	NNW CM(1)	NNQ M^3/sec(3)	Period	MW CM	MQ(3) M^3/sec	Date	HHW CM	HHQ M^3/sec (3)
04 0353(4)	308	-	-	76.5	80.639 80.64 *	1896-1905 22, 23 Oct 1921*	0 -59*	-	1896-1905	265	800-1000	1896-1905 1878*	691 800*	3400
1893(4)	263	61,000 (at Km 257)	-	72.5	76.361 76.24 *	1896-1905 23 Jul 1921*	18 -26*	183	1896-1905	420	825-1000	1896-1905 18 Apr 1932*	960 1013*	3420
2571(4)	225	63,500	-	72.2	76.620 76.62 *	1896-1905 1 Sep 1943*	-53.5 -68*	186	1896-1905	353	875-1060	1896-1905 25 Jul 1923*	800 900*	3540
X 360375(5)	177	-	-	70.0	74.682	1896-1905	80	-	1896-1905	342	900-1060	1896-1905	709	3580
400420(5)	160	-	-	65.8	72.636	Prior to 1911	1		5 yrs. prior to 1904	336	1180-1400	Prior to 1911	810	4000
425603(5)	136	87,500	-	67.2	72.226 72.22 *	Prior to 1911 1890*	14 14*	250	1922-1932	319	1180-1450	Prior to 1911 12 Dec 1944*	703 768*	4050
Y 152233(5)	2.5	-	-	-	-	-								
180250(5)	0	95,400	-	-	68.23 *	28 Oct 1921*	130*	-	-	-	-	6-12 Apr 1940*	714*	4400

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NOTES: See Page 1, Table 3.

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TABLE 4

MAJOR HYDRO-ELECTRIC PROJECTS

SAVA RIVER BASIN

Stream	No. (1)	Project*	North Latitude* (Deg.-Min.)	East Longitude* (Deg.-Min.)	Thermal or Hydro	Electric Capacity (KW)	Status(2)
Sava Dolinka	1	JESENICE	46-30	14-05	T & H	10,000	op. 1948
	2	VINTGAR pri BLEDU	46-24	14-05	H	1,200	op. 1946
	3	MOSTE	46-30	14-10	H	25,000	cp. 1952
	4	ZIROVNICA or ZAVRSNICA	46-24	14-08	H	2,500	op. 1951
Sava	5	MEDVODE(4)	46-10	14-20	H	15,000	U.C. 1951
	6	KRANJ	46-20	14-20	T & H	1,910	op. 1948
	7	TACEN	46-06	14-30	H	1,800	op. 1946
	8	ST. VID	46-10	14-30	H	1,020	op. 1948
	9	SKOFIA LOKA	46-08	14-18	H	1,000	op. 1946
Ljubljana	10	LJUBLJANA	46-03	14-30	H	(3)	-
	11	FUZINE	46-05	14-40	H	2,475	op. 1948
	12	FUZINE pri LJUBLJANA	46-04	14-38	H	1,300	op. 1946
Kupa	13	OZALJ I & II	45-38	15-27	H	3,500	U.C. 1951
Vrbas	14	BANJA LUKA	44-46	17-10	H	-	U.C. 1951
	15	JAJCE I-VI	44-21	17-17	H	8,000-35,000	-
Bosna	16	SARAJEVO	43-50	18-20	T & H	4,100	op. 1948
	17	SARAJEVO II	-	-	H	1,800	op. 1943
	18	MESICI	43-46	18-58	H	-	Comp 1950
	19	BOGATIC	43-48	18-23	H	10,000	Comp 1948
Drina	20	DRINA I (BAJINA BASTA)	43-55	19-40	H	50,000	U.C. 1948
	21	DRINA II	-	-			st. 1949
	22	DRINA III (ZVORNIK)	44-23	19-07	H	100,000	U.C. 1952

* Sources differ as to exact names and locations of projects; data shown represents that considered most likely; also
(1) Site number as shown on General Map, Plate 1.
(2) op.-operating; cp.-probable completion; u.c.-under construction; st.-started.
(3) , million kwh per year
(4) Another plant of similar name (MEDVODE or MEDVODJE) at 46-25 N, 14-24 E of 95-120 million KWH reported as completed

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TABLE 4

MAJOR HYDRO-ELECTRIC PROJECTS

SAVA RIVER BASIN

Stream	No. (1)	Project*	North Latitude* (Deg.-Min.)	East Longitude* (Deg.-Min.)	Thermal or Hydro.	Electric Capacity (KW)	Status (2)	Remarks
Sava Dolinka	1	JESENICE	46-30	14-05	T & H	10,000	op. 1948	
	2	VINTGAR pri BLEDU	46-24	14-05	H	1,200	op. 1946	On a tributary near JESENICE
	3	MOSTE	46-30	14-10	H	25,000	cp. 1952	See Par. 2-10 & Exhibit B.
	4	ZIROVNICA or ZAVRSNICA	46-24	14-08	H	2,500	op. 1951	On tributary just below MOSTE Damsite
Sava	5	MEDVODE(4)	46-10	14-20	H	15,000	U.C. 1951	Either on SORA or SAVA near confluence
	6	KRANJ	46-20	14-20	T & H	1,910	op. 1948	
	7	TACEN	46-06	14-30	H	1,800	op. 1946	Probably on a tributary of SAVA
	8	ST. VID	46-10	14-30	H	1,020	op. 1948	do
	9	SKOFJA LOKA	46-08	14-18	H	1,000	op. 1946	do
Ljubljana	10	LJUBLJANA	46-03	14-30	H	(3)	-	Proposed for 1952-56
	11	FUZINE	46-05	14-40	H	2,475	op. 1948	Aerial photos show 2 small dams in this vicinity
	12	FUZINE pri LJUBLJANA	46-04	14-38	H	1,300	op. 1946	do
Kupa	13	OZALJ I & II	45-38	15-27	H	3,500	U.C. 1951	Two plants
Vrbas	14	BANJE LUK	44-46	17-10	H		U.C. 1951	
	15	JAJCE I-VI	44-21	17-17	H	8,000-35,000	-	6 plants; in 1951: I started, II under construction, III-VI in planning stage
Bosna	16	SARAJEVO	43-50	18-20	T & H	4,100	op. 1948	On DUDIN-HRID River, right tributary of BOSNA
	17	SARAJEVO II	-	-	H	1,800	op. 1943	do
	18	HESICI	43-46	18-58	H	-	Comp 1950	
	19	BOGATIC	43-48	18-23	H	10,000	Comp 1948	On ZELEZNICA River
Drina	20	DRINA I (BAJINA BASTA)	43-55	19-40	H	50,000	U.C. 1948	100 km above ZVORNIK
	21	DRINA II	-	-	-	-	st. 1949	57 km above ZVORNIK
	22	DRINA III (ZVORNIK)	44-23	19-07	H	100,000	U.C. 1952	

* Sources differ as to exact names and locations of projects; data shown represents that considered most likely; also may be some omissions and duplications in the table.
(1) Site number as shown on General Map, Plate 1.
(2) op.-operating; cp.-probable completion; u.c.-under construction; st.-started.
(3) 5 million KWH per year
(4) Another plant of similar name (MEDVODE or MEDVODJE) at 46-25 N., 14-24 E of 95-120 million KWH reported as completed in 1952.

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TABLE 4

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(From ZAGREB (29/5390) to JESENICE (10/0460)).

NAME OF WATERWAY:- R. SAVA

Series No. Y.2

Y. WATERWAYS

Type:-

Sheet No. 1

Serial No.	Location and Map Ref.	Information Source & Photo Quality	Item	Width of Bed	Wet Gap with Date	Bed	Depth	Current	Banks - Width & Depth.	Approach Roads and surrounding terrain.	REMARKS.
1.	[illegible] 29/525906	60PR-66A 4005A and Ground Photo.	Existing Ferry Site.		305' (14 Aug)	Sand and Silt.			Low sloping	Rough track on each side already built.	Good site for floating bridge. Approach tracks need improvement. See Detail Sketch No. 1.
[illegible]	ZARED 29/517990	"	Rly Bridge. Bowstring Girder Span (over river) plus plate girder spans.		415'	Sand			Low. Gently rising rough ground.		See Detail Sketch No. 1. See Ground Photo No. 2.
3.	[illegible] 29/515592	"	Road Bridge. Continuous welded plate. Girder spans with concrete abutments.		440'	Sand			South:- [illegible], flat. North:- Steep, and approx 5'-10' high.		On the south bank the bridge crosses the end of a small lake separated from the river by a narrow bank. The southernmost pier stands in the lake. Including the lake the wet gap is 550ft. Probably class 40. bridge. See detail of br in Detail Sketch No.1. See Ground Photo No.3.

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TABLE 5
1 of 16

NAME OF WATERWAY:- R. S.VA   Serial No. Y.2   Y. WATERWAYS.

Type:-   Sheet No. 2.

Serial No.	Location and Map Ref.	Information Source & Photo Quality.	Item	Width of Bed	Wet Gap with Date	Bed	Depth	Current	Banks - Width & Depth.	Approach Roads and surrounding terrain.	REMARKS
4.	[illegible] 28/420930	SK452 3153-4 A.	Road & Railway Br.	330'	270' 25 Aug 44. (Up-stream)	Silt and Sand.			North:- Gently sloping. South:- steep. sloping.	Approach roads on embankments. Flat country to South. To the North it is flat and marshy.	A 6 Span Steel Girder Bridge. Each span 120'. Ht. 35' approx. above water level. At the br site the water is shallow and there is a sand bar in the middle of the river. Road 15' wide. Clear width 22'.
5.	N. of [illegible] 28/308981	SK452 4186-7	Ferry	340'	300' Elsewhere Wet Gap is 340'	Sand and Silt			Fairly steep sloping.	North:- Approach road built on a bar jutting out into the river.	A small ferry exists at this point. Approach roads to main road on the NORTH are narrow (9' approx) and approx. 2½ miles long before reaching main road.

NAME OF WATERWAY:- R. S.V.

TYPE:-

Series No. Y.2

Y. WATERWAYS

Sheet No. 3.

Serial No.	Location and Map Ref.	Information Source & Photo Quality	Item	Width of Bed	Wet Gap with Date	Bed	Depth	Current	Banks - Width & Depth.	Approach Roads and surrounding terrain.	REMARKS
6.	[illegible] 23/25031,	60[illegible]-577 3030-1 B.	Ferry.	303'	290'				Very Low. Sloping on both sides.	Very poor track approaches from SOUTH. Long approach to main road. Flat scrub land.	Light Civil ferry site. Good wet bridging site.
	[illegible] 28/230[illegible]	P.547 4078-9	Road Bridge, Steel Girder.	290'	27[illegible]'	Silt and Sand.			South:- Gently sloping, backed by grassland. North:- Steeper, backed by buildings to East & stream to WEST.	Road approx. 15-20' wide. Straight approaches. Low flat land surrounding.	A 2 Span (19?' each) Steel Girder Bridge. Reported strong and probably take class 40 loads. See Detail No. 2. for dimensions.

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[illegible] N. S.V. Series No. Y.2 Y. [illegible]

Type:- Sheet No. 4.

Location	Location and Map Ref.	Information Source Photo Quality	Item	Width of Bed.	Wet Gap with Date	Bed	Depth	Current	Banks - Width & Depth.	Approach Roads and Surrounding terrain.	REMARKS.
8.	[illegible] 26/143087	SE152 4073-4D.	Road Bridge Masonry Arch.	370'	360'	Rock and Sand.			North:- Steep and rocky. South is gently sloping.	Curved approaches to bridge at each end.	O.A.L. = 530'. 110(?) span Masonry Arch Bridge. Arch span 45. Clear width 22'.
	[illegible] 12/003.36	60[illegible]-310 3003 4003	Road Bridge. 1 Steel girder Truss and 7 Masonry Arches	370'	350'	Sand.			North:- Sloping. South:- Steep.	Right angle approaches. Hilly terrain.	1 Steel Girder Truss of 90' span and 7 Masonry Arches each 40' span. Clear width 15' Overall length of Br 450'
10.	[illegible] 12/5971.	"	Railway Br. Steel Girder Truss.	450'	440'	"			Steep.	-	3 Span Steel Girder Bridge, each span 170'. Clear width 20'. Overall length 570'.

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[illegible] OF [illegible] [illegible] S.W. Series No. Y.2 Y. [illegible]

[illegible] Sheet No. 6.

[illegible]	Location and Map. Ref.	Information Source & Quality.	Item	Width of Bed.	Wet Gap with Date	Bed	Depth	Current	Banks - Width & Depth.	Approach Roads and surrounding terrain.	REMARKS.
14.	3C.M. of [illegible] 12/796.67	[illegible] 3194-5C	Road Bridge.	140'	110' (25 Aug)	Silt			Very Steep.	Rt. angle approaches to bridge. Hilly terrain.	Overall length 220'. 3(?) Spans (dimension not possible). Clear width 15ft.
[illegible]	[illegible] of [illegible] 14/786.56	[illegible] 3196-7	Wooden Foot Bridge.	130'	110' (25 Aug)	Rock & Silt.			Steep & wooded.	Right angle approaches.	Overall length 130'. No. of spans unknown.
[illegible]	S.W. 12/694224		Road Br. Central Span Steel (?).	200'	130'	Silt & Gravel			West:- Sloping. East:- V. steep.		Central span 110'. Two approach spans (one each side) 75'. Clear width 8 ft. ONLY. Overall length 250'.

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TABLE 5
6 of 16

RESTRICTED
SECURITY INFORMATION

[illegible]:- R. SAVA   Series No. Y.2   Y. [illegible]

Type:-   Sheet No. 7.

Serial No.	Location and Map Ref.	Information Source & Photo Quality	Item	Width of Bed	Wet Gap with Date	Bed	Depth	Current	Banks - Width & Depth.	Approach Roads and surrounding terrain	REMARKS.
[illegible]	LITIJA 11/637188	[illegible]-452 4209-10B	Road Bridge. Wooden.	395'	100' & 200'. Sand bar in centre 25 Aug.				South:- Vertical. North:- Sloping.	Curved approaches. Built up area road br site.	Overall length 515 ft. Clear width 22 ft. 9 Spans. Load Class 3.
[illegible]	Mr. [illegible] 11/635214	3208-9B	Rly Bridge. Steel Truss.	470'	210' & 120'. Island in middle. 25 Aug.				Low steep banks.	Flat open terrain.	3 Span Steel Girder Bridge. Each span 175 ft. Overall Length 500 ft. Clear width 330 ft. Two Masonry Piers.
19.	DOL[illegible] 11/518219	4213B.	Rly Bridge. Skew Bridge and possible ferry site.	200'	175' (25 Aug).				Low sloping.	Flat Terrain.	Multi Span Bridge. Overall length 850'. Only 3 spans across river. Spans 65 ft. There is an existing ferry site upstream of the rly br. Rough tracks lead down to the water's edge. Wet Gap 170' (Aug).

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TABLE 5
7 of 16

[illegible]   Series [illegible]   Y. [illegible]

Type: Sheet No. 8

[illegible]	Location and Map Ref.	Information Source & Quality	Item	Width of Bed.	Wet Gap with Date.	Bed	Depth	Current	Banks - Width & Depth	Approach Roads and surrounding terrain.	Remarks
[illegible]	[illegible] 11/449217	1550-476 4136-7	Road Bridge. Masonry (?).	190'	185' (29 May).	Silt.			Sloping banks.	Open and straight approaches. Flat country.	Overall Length 265 ft. Clear Width 15 ft. Number of spans not visible.
[illegible]	[illegible] 11/[illegible]	[illegible]-983 3059-60	Rly Bridge. Steel Girder Bridge.	160'	160' (4 Apr)	•			Vertical Banks.		3 Span Steel Girder Bridge. Central span 190'. Outer spans 140 ft. Masonry Piers. Access from road onto each side of railway. See Detail Sketch No. 3.
[illegible]	[illegible] 11/397235	•	Road Bridge.	160'	160' (4 Apr)	•			•	Road on embankment approaches.	3 Span Girder Bridge. Central Span 190', outer spans 133'. Clear width 20'. See Detail Sketch No. 3.
[illegible]	[illegible] 11/[illegible]	60PR-319 3111-2	Road Bridge. Concrete Arches and Steel Girder Span.	160'	140' (14 April)				Steep, sloping.	Straight approaches.	One span (steel girder) 235'. 2 Spans 55' (RC or Arches) on SOUTH side. Overall length 475'.

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8 of 16

[illegible] Series No. Y.2 Y. [illegible]

Type- Sheet No. 9.

[illegible]	Location and Map Ref.	Information Source & Photo Quality.	Item.	Width of Bed.	Wet Gap with Date	Bed	Depth	Current	Banks - Width & Depth.	Approach Roads and surrounding terrain.	[illegible]
[illegible]	[illegible] 11/137258	60gm-319 3111[illegible]	Footbridge ? Suspension Bridge ?	220'	160' (14 [illegible]).	Silt.			Sloping.	Straight. North approach on embankment.	1 Span 275'. - Light structure.
	[illegible] 11/[illegible]	[illegible] 3217-8	Footbridge. Probably Masonry or Wood.	130'	25' (25 Aug).	Rock.			Steep.	Approach track 15' wide.	Overall Length 175'. Number of spans unknown.
	[illegible] 11/325306	[illegible]-2	Road Bridge. Masonry Arch.	195'	160' (25 Aug).	Silt.			Sloping.	Hairpin Bend on approach road from SOUTH.	Overall length 275'. 6 Spans 35 ft each. Clear width 20 ft.
27.	[illegible] 11/267365	422?-30	Road Bridge Probably R.C. Spans on R.C. Piers. Skew bridge.	200'	45' (25 Aug).	Silt.			Wooded & sloping.	Curved approaches.	Overall Length 330 ft. 7 Spans 35 ft. each. Clear width 22 ft. See Detail Sketch No. 4, Bridge 4.

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NAME OF WATERWAY:- R. S.Y.. Series No. Y.2 Y. WATERWAYS

Type:- Sheet No.10.

Serial	Location and Map Ref.	Information Source & Photo Quality	Item	Width of Bed	Wet Gap with Date		Depth	Current	Banks - Width & Depth.	Approach Roads and surrounding terrain.	REMARKS.
	KILND 11/467336	SU-452 4229-30B.	Timber Footbridge or Light Vehs. Bridge.	275'	220' Very shallow (25 Aug).	Silt			Sloping.	Straight. Built up surroundings	This bridge 440 ft long. 10 spans of 35 ft. each. This br is built on the site of the old br destroyed in 1941. It is approx. 10 ft. wide and may take light loads. See Detail Sketch No. 4, Bridge B.
	KILND 11/260397	SU-452 4231-2	Railway Br.	165'	Almost dry Aug.	Silt and gravel.			Low, sloping.	-	4 Span. Steel Girder Bridge. Overall Length 580'. Each span 140'. Only 2 spans over river. - remainder over flat land. See Detail Sketch No. 4., Bridge C.
33.	DYIN 10/177[illegible]	SU-452 4238-9B.	Road Bridge.	[illegible]	Dry 25 Aug.	Gravel. Nil.		-	Low sloping.	Rt. angle approaches. Flat terrain.	[illegible] Span Masonry or R.C. bridge. Each span 40'. Overall length 330'. Clear width 15'.

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TABLE 5
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[illegible] OF [illegible]:-

Type:-

Series No. Y.2

[illegible]

Sheet No. 11.

Ser. No.	Location and Map Ref.	Information Source & Photo Quality	Item	Width of Bed	Wet Gap with Date	Bed	Depth	Current	Banks - Width, Depth.	Approaches Roads and surrounding terrain.	Remarks.
[illegible]	DOBIL[illegible] 10/179463	5[illegible]-452 1240-1n.	Footbridge or Light Rd Br.	190'	Dry (25 Aug).	Gravel.	-	-	Steep, [illegible].	Straight [illegible].	8 (?) Span [illegible] (?) bridge. [illegible] Span [illegible]. Overall length [illegible] ft. Clear width [illegible] ft. This bridge [illegible] [illegible] on the [illegible].
[illegible]	[illegible] 10/163478	60PR-39 3065C.	Railway Br. Lattice Girder Bridge.	220'	Nil. Dry 25 Aug.	Gravel.	Nil.	Nil.	St[illegible], vertical.	-	4 Span Girder [illegible] span [illegible]. Overall [illegible]. Clear width [illegible].
33.	[illegible] 10/1[illegible]500	60PR-39 3067C.	Road Bridge.	200'	Nil. Dry 25 Aug.	Gravel.	Nil.	Nil.	Steep, vertical.	Straight.	Overall length [illegible] ft. Clear width [illegible]. [illegible] [illegible] [illegible].

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[illegible] OF [illegible] - R. S.V.

Type -

Series No. Y.2

[illegible]

Sheet No. 12.

Serial No.	Location and Map Ref.	Information Source & Photo Quality	Item	Width of Bed	Wet Gap with Date	Bed	Depth	Current	Banks - Width & Depth.	Approach Roads and surrounding terrain.	REMARKS.
[illegible]	[illegible] 1[illegible]/1005[illegible].	40FR-89 4066G	Road Br. Masonry Arch.	100'	55' Shallow 1 Nov.	Silt.			Steep, wooded.	Straight approach roads.	Overall length 130 ft. 4 (?) Spans 35 ft each. Clear width 22'. It appears that the old bridge (to the [illegible]) has been demolished. Approach roads still exist.
5.	[illegible] 10/[illegible]	3140-1B	Railway Br. Lattice Girder.	110'	[illegible]. Dry 18 July.	Gravel	Nil	Nil	Very steep and deep.	-	Overall length 540'. One clear span 140ft. over river. Other spans not clearly defined.
[illegible].	[illegible] 13/[illegible]	3140-1B	Road Bridge. Light Lattice Girder structure.	75'	Nil. Dry 18 July.	"	"	"	Very steep.	Bad approach rds and Rt. angle turns onto br.	Overall length 85ft. Clear width 15ft. Appears to be only suitable fo light loads.
7.	[illegible] 1[illegible]/[illegible]	3140-1C	Road Br.	70'	Nil. Dry 18 July	"	"	"	Low sloping.	Straight approaches.	Overall length 70'. Possibly 2 Span Masonry Br - Details not clear.

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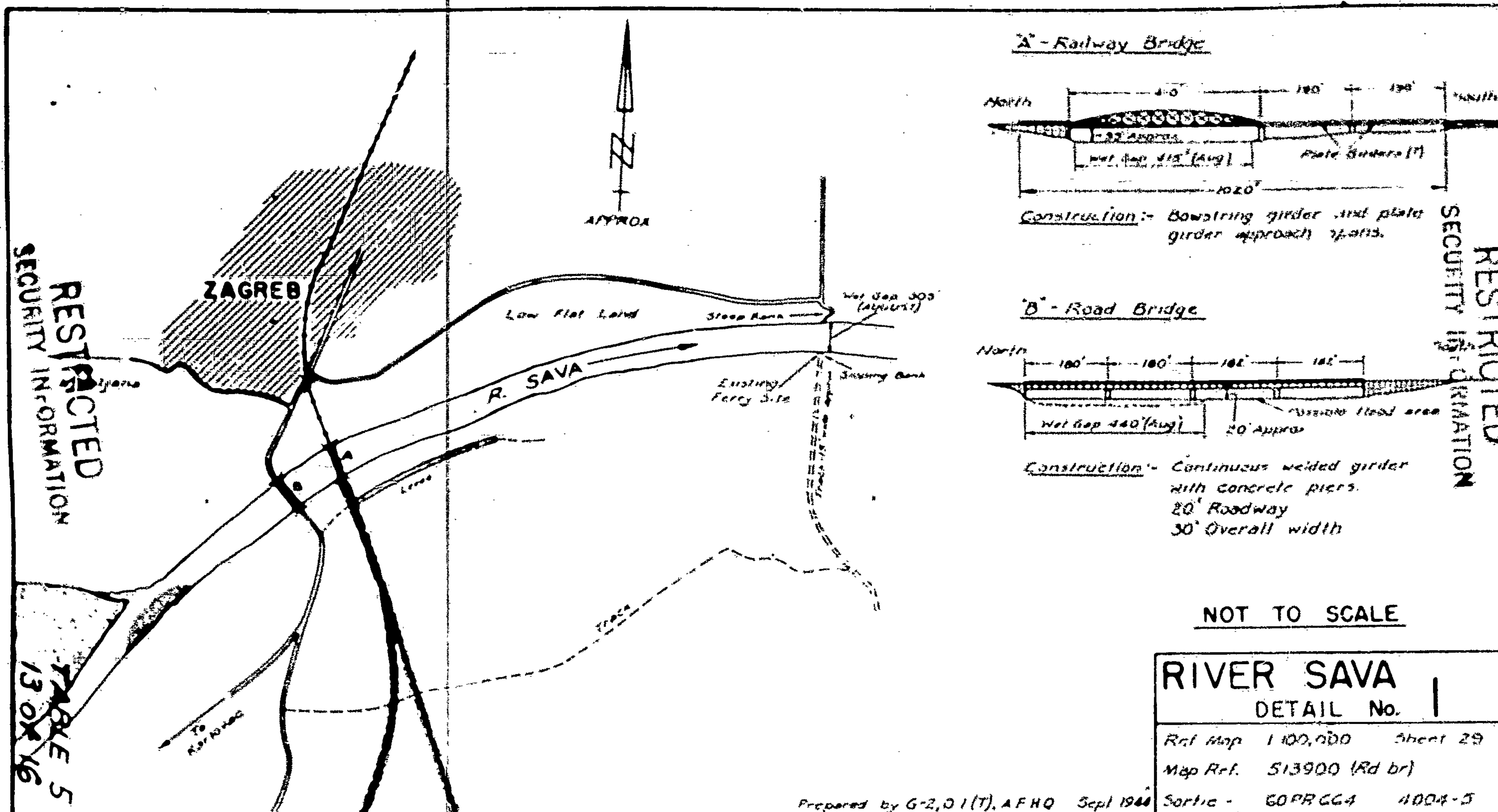
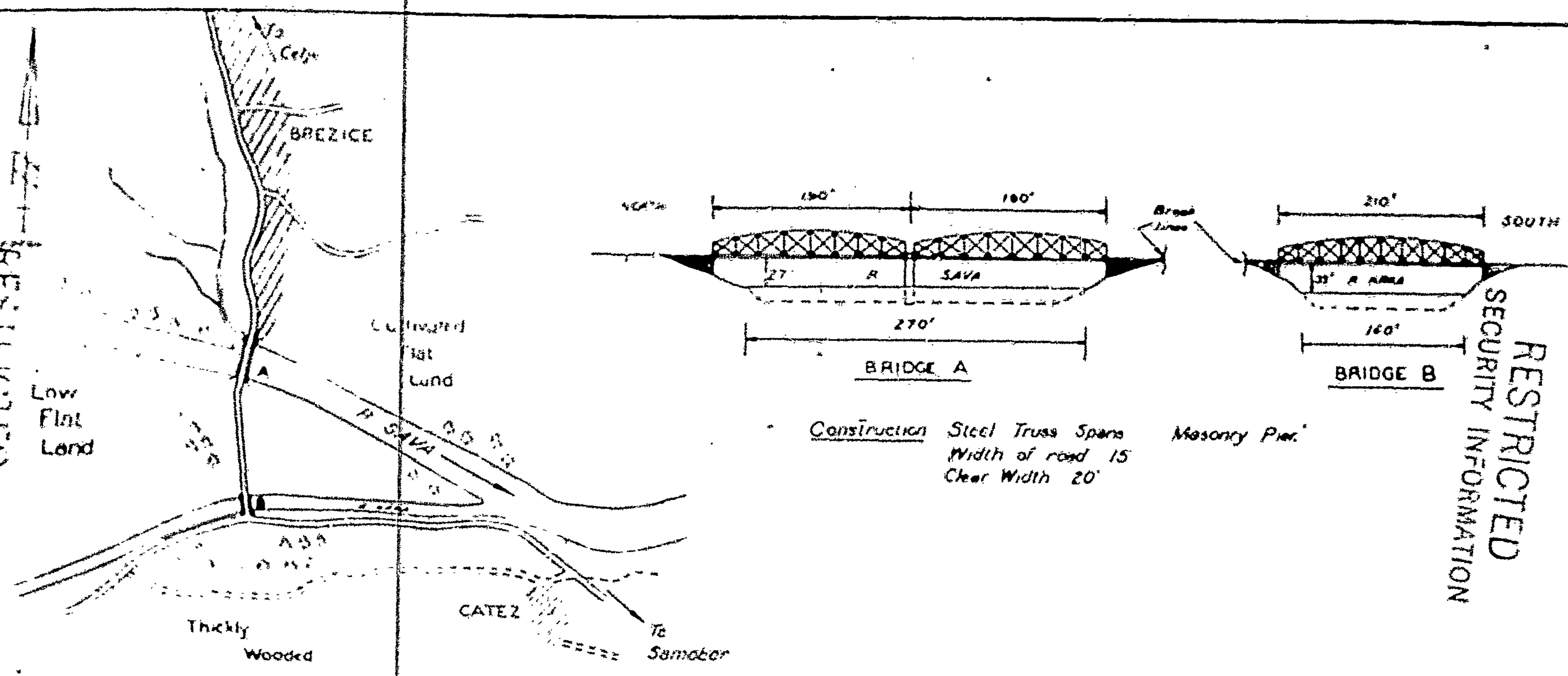


Printed by 13 Corps Fd Svy Coy R.E. Oct 1944



NOT TO SCALE.

Prepared by G-2, 01 (T) AFHQ Sept 44

RIVER SAVA.
DETAIL No. 2.

Ref Map 1 100,000 Sheet 28
Map ref 231020
Sortie P 547 4078-9

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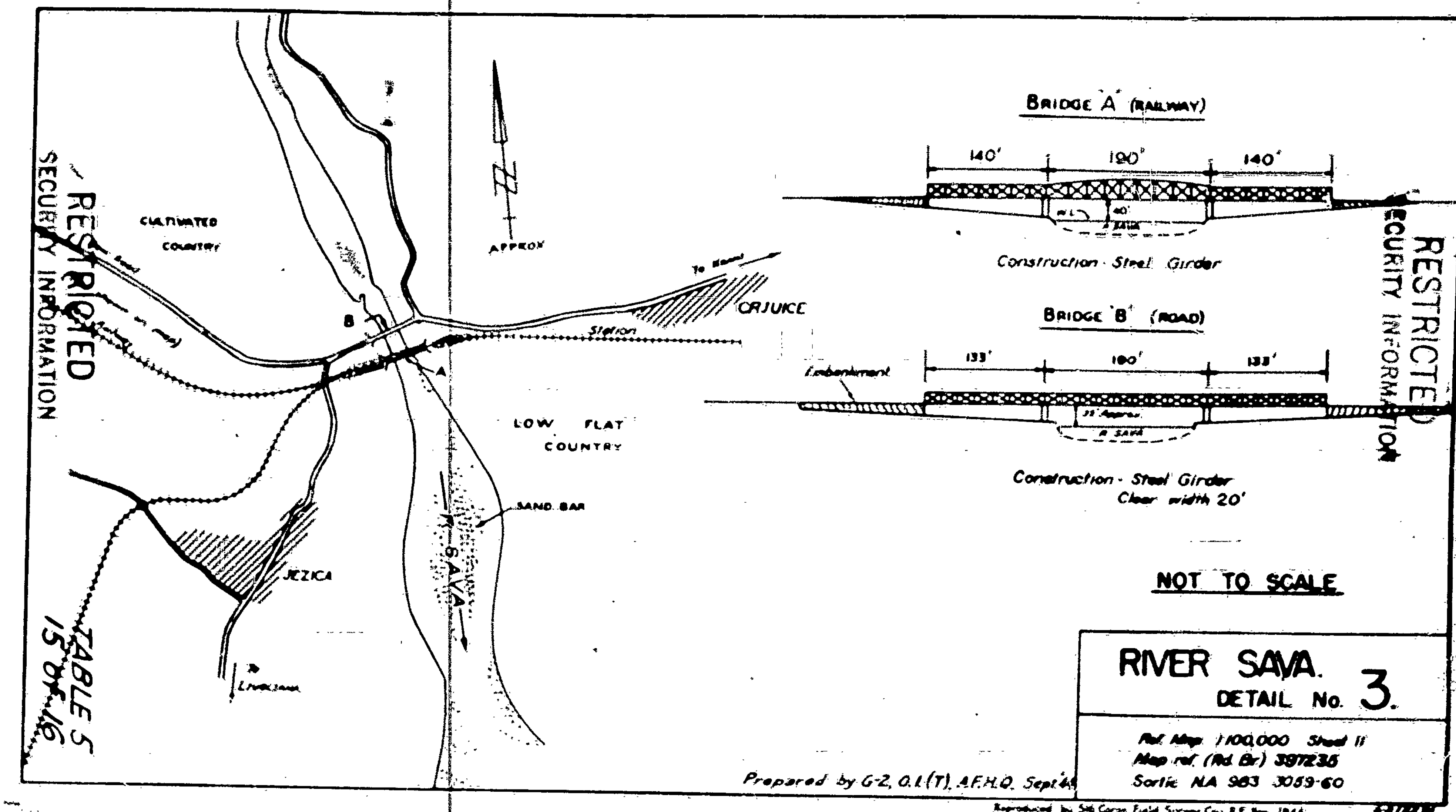

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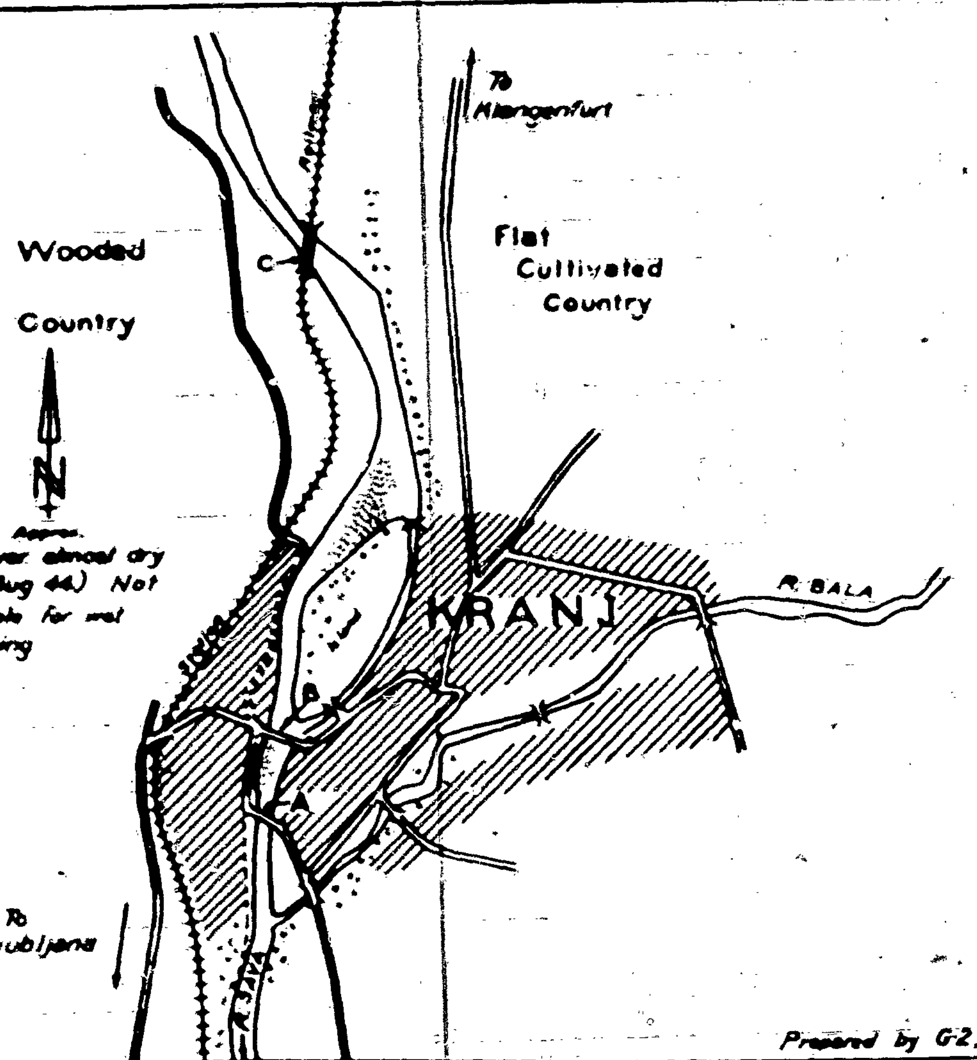
SECURITY INFORMATION



NOTE:- River almost dry (25 Aug 44) Not suitable for wet bridging

Bridge A 7 span masonry or R.C. bridge. Each span 35' apprx. Clear width 22 ft.

Bridge B 10 span timber footbridge (?) or light vehicle bridge. Each span 38'. Overall length 440' Clear width 10 ft.

Bridge C (Rly) 4 span steel girder bridge. Each span 140' Overall length 580 ft

Note:- Not sufficient detail known to show sketches of above bridges.

NOT TO SCALE

RIVER SAVA. DETAIL No. 4.

Ref. Map 1:100,000. Sheet 11
Map ref. (Br. A) 267385
Series:- G.M. 452 4030-1

Prepared by G-2, O1 (T) AFHQ. Sept 44.

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TABLE 6

INUNDATION EFFECTS OF STILLWATER BARRIERS

Bridge Serial No.	River Km	Map AMS-M702 (GSGS-4719)	U.T.M. Grid	Location	Pond Elev. m.u.A.	Approx. Elev. above MW	Dimensions of Inundated Areas: Length* Km	Average Width Km	Average Depth m	Area Km²	Volu Mil. m
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	LJUBLJANA RIVER										
-	852	11-III	618995	LJUBLJANA Rd. Br.	290	6.5	18	3.5	1.0	64.6	64.6
	SAVA RIVER										
23	852	11-III	485072	VIZMARJE-TACEN Rd. Br.	No significant flooding						
21	849	11-III	629056	RR Br. nr. JESICA 3 spans Total opening 143 m Stream width 49 m	297	10.0	3.5	1.3	4.5	2.2	10.1
20	842	11-II	679037	PEONIK (nr. SV. JAKOB)	No significant flooding						
19	833	11-II	752040	DOLSKO RR Br. 3 spans Total opening 260 m Stream width 53 m	265	7.0	3.6	0.7	1.3	1.6	3.1
- -	833 to 757	11-II 26-IV	752040 378898	DOLSKO [illegible] to VIDEN	River runs in gorge						
7	735	28-I	460830	BREŽICE Rd. Br. 2 spans Total opening 116 m Stream width 82 m	141	3 m (above bank)	7.0	0.5	3.5	1.5	5.0
-	700	29-IV	7471	ZAGREB	116	4	No significant flooding				
-	595	45-IV	082372	SISAK Rd. Br.	96	3	10	5-8	1 or more	50-60	50-60
-	506	46-IV	466141	JASENOVAC RR Br.	95	4	25-30	2-5	1 or more	40-60	40-60
-	460	46-II	770420	STARA-GRADIŠKA Rd. Br.	94	4	50-60	7-10	1 or more	300-350	300-[illegible]

*Length represents straight line dimension of Pool and is not necessarily along stream

Prepared by Military Hydrology R&D Branch, Washi

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TABLE 6

INUNDATION EFFECTS OF STILLWATER BARRIERS

Map AMS-M792 (GSGS-4786)	U.T.M. Grid (4)	Location (5)	Dimensions of Inundated Areas: Pond Elev. m.M.A. (6)	Approx. Elev. above MW (7)	Length* Km (8)	Average Width Km (9)	Average Depth m (10)	Area Km^2 (11)	Volume Mil. m^3 (12)	Remarks (13)
11-III	616995	LJUBLJANA Rd. Br.	296	6.5	18	3.5	1.0	64.6	64.6	(1) Will also require blocking of bridge on GRUBER Canal.
11-III	485072	VIZMARJE-TACEN Rd. Br.	No significant flooding							
11-III	629056	RR Br. nr. JESICA 3 spans Total opening 143 m Stream width 49 m	297	10.0	3.5	1.3	4.5	2.2	10.1	(1) Pond Elevation is estimated elevation of bridge deck. (2) Flooding confined to right bank.
11-III	679037	PECNIK (nr. SV. JAKOB)	No significant flooding							
11-II	752040	DOLSKO RR Br. 3 spans Total opening 260 m Stream width 53 m	265	7.0	3.6	0.7	1.3	1.6	3.1	(1) Pond Elevation is estimated elevation of bridge deck. (2) Flooding confined to left bank.
11-II 24-IV	752040 378598	DOLSKO [illegible] to VIDEM	River runs in gorge							
24-I	460830	KRŠKO Rd. Br. 2 spans Total opening 116 m Stream width 82 m	141	.9 m (above bank)	7.0	0.5	3.5	1.5	5.0	
24-IV	7471	ZAGREB	116	4	No significant flooding					
45-IV	462372	SISAK Rd. Br.	96	3	10	5-8	1 or more	50-60	50-60	(1) May also require blocking of bridge on the KUPA River. (2) Existence of effective embankment to hold pool, on left bank, doubtful. (3) Flooding confined to left bank.
46-IV	466141	JASENOVAC RR Br.	95	4	25-30	2-5	1 or more	40-60	40-60	(1) Pool must hold along 6 km of RR embankment on left bank and along 5 km on right.
46-II	770480	STARA-GRADIŠKA Rd. Br.	94	4	54-60	7-10	1 or more	300-350	300-350	(1) Flooding mainly on left bank. (2) Must hold on 6.5 km of embankments on right bank.

*Represents straight line dimension of Pond and is not necessarily along stream.

Prepared by Military Geology, RSJ Branch, Washington Dist., Corps of Engineers

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TABLE 7
SUMMARY OF EFFECTS OF ARTIFICIAL FLOOD WAVES AND FLOW VARIATIONS

Artificial Flood No.	Type of Outflow	Location	River Km.	Discharge Initial m3/sec	Discharge Increase m3/sec	Discharge Crest m3/sec	River Depth Initial m	River Depth Increase m	River Depth Crest m	Overflow(1) m	River Width Initial m	River Width Crest m	Mean Initi[al] m/se[c]
1	a. MOSTE DAM Breach plus Outlets	MOSTE DAM	904	15	315	330	-	-	-	-	-	-	-
	b. 10 m. wide	OTOČE	885	55	150	205	2.0	0.7	2.7	Within banks	75	85	1.6
	c. 509 m.ü.A. Breach Elev.	SMLEDNIK	861	60	120	180	0.6	0.7	1.3	Within banks	70	100	1.5
	d. 514 m.ü.A. Water Elev.	LITIJA	813	185	85	270	2.4	0.3	2.7	Within banks	155	160	1.7
		BREZICE	735	240	70	310	2.8	0.3	3.1	Within banks	100	110	1.8
		ZAGREB	700	250	65	315	3.0	0.3	3.3	Within banks	210	215	0.8
2	a. MOSTE DAM Breach plus Outlets	MOSTE DAM	904	15	575	590	-	-	-	-	-	-	-
	b. 10 m. wide	OTOČE	885	55	270	325	2.0	1.0	3.0	Within banks	75	85	1.6
	c. 509 m.ü.A. Breach Elev.	SMLEDNIK	861	60	205	265	0.6	1.0	1.6	Within banks	70	115	1.5
	d. 517 m.ü.A. Water Elev.	LITIJA	813	185	130	315	2.4	0.4	2.8	Within banks	155	160	1.7
		BREZICE	735	240	105	345	2.8	0.4	3.2	Within banks	100	110	1.8
		ZAGREB	700	250	95	345	3.0	0.4	3.4	Within banks	210	215	0.8
3	a. MOSTE DAM Breach plus Outlets	MOSTE DAM	904	15	1530	1545	-	-	-	-	-	-	-
	b. 10 m. wide	OTOČE	885	55	675	730	2.0	1.4	3.4	Within banks	75	130	1.6
	c. 509 m.ü.A. Breach Elev.	SMLEDNIK	861	60	520	580	0.6	1.9	2.5	Within banks	70	155	1.5
	d. 523.5 m.ü.A. Water Elev.	LITIJA	813	185	340	525	2.4	1.0	3.4	Within banks	155	165	1.7
		BREZICE	735	240	260	500	2.8	0.8	3.6	Within banks	100	120	1.8
		ZAGREB	700	250	235	485	3.0	0.9	3.9	Within banks	210	220	0.8
4	a. MOSTE DAM Breach plus Outlets	MOSTE DAM	904	15	335	350	-	-	-	-	-	-	-
	b. 10 m. wide	OTOČE	885	55	215	270	2.0	0.9	2.9	Within banks	75	85	1.6
	c. 518.5 m.ü.A. Breach Elev.	SMLEDNIK	861	60	175	235	0.6	0.9	1.5	Within banks	70	110	1.5
	d. 523.5 m.ü.A. Water Elev.	LITIJA	813	185	130	315	2.4	0.4	2.8	Within banks	155	160	1.7
		BREZICE	735	240	110	350	2.8	0.4	3.2	Within banks	100	110	1.8
		ZAGREB	700	250	105	355	3.0	0.4	3.4	Within banks	210	215	0.8
5	a. MOSTE DAM Breach plus Outlets	MOSTE DAM	904	15	525	540	-	-	-	-	-	-	-
	b. 20 m. wide	OTOČE	885	55	250	305	2.0	1.0	3.0	Within banks	75	85	1.6
	c. 518.5 m.ü.A. Breach Elev.	SMLEDNIK	861	60	215	275	0.6	1.0	1.6	Within banks	70	120	1.5
	d. 523.5 m.ü.A. Water Elev.	LITIJA	813	185	145	330	2.4	0.5	2.9	Within banks	155	160	1.7
		BREZICE	735	240	120	360	2.8	0.4	3.2	Within banks	100	110	1.8
		ZAGREB	700	250	110	360	3.0	0.6	3.6	Within banks	210	215	0.8
6	a. MOSTE DAM Breach plus Outlets	MOSTE DAM	904	15	1370	1385	-	-	-	-	-	-	-
	b. 20 m. wide	OTOČE	885	55	575	630	2.0	1.4	3.4	Within banks	75	120	1.6
	c. 513.5 m.ü.A. Breach Elev.	SMLEDNIK	861	60	435	495	0.6	1.7	2.3	Within banks	70	145	1.5
	d. 523.5 m.ü.A. Water Elev.	LITIJA	813	185	280	465	2.4	0.9	3.3	Within banks	155	165	1.7
		BREZICE	735	240	205	445	2.8	0.5	3.3	Within banks	100	120	1.8
		ZAGREB	700	250	190	440	3.0	0.7	3.7	Within banks	210	220	0.8

(1) Approx. height of water above river banks
(2) Approx. total duration of rise
(3) Levees intact/levees breached

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TABLE 7
SUMMARY OF EFFECTS OF ARTIFICIAL FLOOD WAVES AND FLOW VARIATIONS

	Location	River Km.	Discharge Initial m^3/sec	Discharge Increase m^3/sec	Discharge Crest m^3/sec	River Depth Initial m	River Depth Increase m	River Depth Crest m	Overflow(1) m	River Width Initial m	River Width Crest m	Mean Surface Velocity Initial m/sec	Mean Surface Velocity Crest m/sec	Time from Dam to Start Hours	Time from Dam to Crest Hours	Duration of Rise Days(2)
...s Outlets	MOSTE DAM	904	15	315	330	-	-	-	-	-	-	-	-	0	0	1/4
	OTOČE	885	55	150	205	2.0	0.7	2.7	Within banks	75	85	1.6	2.3	1	3	1/4
...lev.	SMLEDNIK	861	60	120	180	0.6	0.7	1.3	Within banks	70	100	1.5	2.2	4	7	1/2
...v.	LITIJA	813	185	85	270	2.4	0.3	2.7	Within banks	155	160	1.7	1.9	9	14	1/2
	BREZICE	735	240	70	310	2.8	0.3	3.1	Within banks	100	110	1.6	1.9	17	25	1/2
	ZAGREB	700	250	65	315	3.0	0.3	3.3	Within banks	210	215	0.8	1.0	21	30	3/4
...s Outlets	MOSTE DAM	904	15	575	590	-	-	-	-	-	-	-	-	0	0	1/4
	OTOČE	885	55	270	325	2.0	1.0	3.0	Within banks	75	85	1.6	2.4	1	3	1/2
...lev.	SMLEDNIK	861	60	205	265	0.6	1.0	1.6	Within banks	70	115	1.5	2.4	3	7	1/2
...v.	LITIJA	813	185	130	315	2.4	0.4	2.8	Within banks	155	160	1.7	1.9	8	13	1/2
	BREZICE	735	240	105	345	2.8	0.4	3.2	Within banks	100	110	1.8	2.0	16	24	1/2
	ZAGREB	700	250	95	345	3.0	0.4	3.4	Within banks	210	215	0.8	1.1	20	29	3/4
...s Outlets	MOSTE DAM	904	15	1530	1545	-	-	-	-	-	-	-	-	0	0	1/2
...v.	OTOČE	885	55	675	730	2.0	1.4	3.4	Within banks	75	130	1.6	2.5	1	3	1/2
...lev.	SMLEDNIK	861	60	520	580	0.6	1.9	2.5	Within banks	70	155	1.5	2.8	3	7	1/2
	LITIJA	813	185	340	525	2.4	1.0	3.4	Within banks	155	165	1.7	2.2	8	13	1/2
	BREZICE	735	240	260	500	2.8	0.8	3.6	Within banks	100	120	1.8	2.0	15	23	3/4
	ZAGREB	700	250	235	485	3.0	0.9	3.9	Within banks	210	220	0.8	1.4	19	28	3/4
... Outlets	MOSTE DAM	904	15	335	350	-	-	-	-	-	-	-	-	0	0	1
...lev.	OTOČE	885	55	215	270	2.0	0.9	2.9	Within banks	75	85	1.6	2.	1	3	1
...lev.	SMLEDNIK	861	60	175	235	0.6	0.9	1.5	Within banks	70	110	1.5	2.3	3	7	1
	LITIJA	813	185	130	315	2.4	0.4	2.8	Within banks	155	160	1.7	1.9	8	14	1
	BREZICE	735	240	110	350	2.8	0.4	3.2	Within banks	100	110	1.8	2.0	16	26	1-1/4
	ZAGREB	700	250	105	355	3.0	0.4	3.4	Within banks	210	215	0.8	1.1	20	32	1-1/4
... Outlets	MOSTE DAM	904	15	525	540	-	-	-	-	-	-	-	-	0	0	3/4
...lev.	OTOČE	885	55	250	305	2.0	1.0	3.0	Within banks	75	85	1.6	2.4	1	3	1
...v.	SMLEDNIK	861	60	215	275	0.6	1.0	1.6	Within banks	70	120	1.5	2.4	3	7	1
	LITIJA	813	185	145	330	2.4	0.5	2.9	Within banks	155	160	1.7	2.0	8	13	1
	BREZICE	735	240	120	360	2.8	0.4	3.2	Within banks	100	110	1.8	2.0	10	25	1
	ZAGREB	700	250	110	360	3.0	0.6	3.6	Within banks	210	215	0.8	1.2	20	30	[illegible]
Outlets	MOSTE DAM	904	15	1370	1385	-	-	-	-	-	-	-	-	0	0	1/2
...lev.	OTOČE	885	55	575	630	2.0	1.4	3.4	Within banks	75	120	1.6	2.5	1	3	1/2
...v.	SMLEDNIK	861	60	435	495	0.6	1.7	2.3	Within banks	70	145	1.5	2.8	3	7	1/2
	LITIJA	813	165	280	465	2.4	0.9	3.3	Within banks	155	165	1.7	2.2	6	13	3/4
	BREZICE	735	240	205	445	2.8	0.5	3.3	Within banks	100	120	1.8	2.0	15	23	3/4
	ZAGREB	700	250	190	440	3.0	0.7	3.7	Within banks	210	220	0.8	1.3	19	28	3/4

...iver banks

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TABLE 2

SUMMARY OF EFFECTS OF ARTIFICIAL FLOOD WAVES AND FLOW VARIATIONS (Continued)

Artificial Flood No.	Type of Outflow	Location	River Km.	Discharge Initial m3/sec	Discharge Increase m3/sec	Discharge Crest m3/sec	River Depth Initial m	River Depth Increase m	River Depth Crest m	Overflow(1) m	River Width Initial m	River Width Crest m
7	a. LJUBLJANA Barrier Breach	LJUBLJANA	852	50	675	725	-	-	-	-	-	-
	b. 10 m. wide	LITIJA	813	185	630	815	2.4	1.9	4.3	Bankfull	155	170
	c. 285 m.ü.A. Breach Elev.	BREZICE	735	240	570	810	2.8	1.6	4.4	Bankfull	100	140
	d. 295 m.ü.A. Water Elev.	ZAGREB	700	250	530	780	3.0	1.7	4.7	Bankfull	210	220
		RUGVICA	664	280	500	780	4.1	3.4	7.5	Bankfull	150	280
		STARA-GRADIŠKA	460	800	340	1140	6.4	2.7	9.1	0.5	190	210/1000(3)
		BRCKO	225	1100	200	1300	7.9	0.4	8.3	0.5	280	285
8	a. LJUBLJANA Barrier Breach	LJUBLJANA	852	50	175	225	-	-	-	-	-	-
	b. 10 m. wide	LITIJA	813	185	165	350	2.4	0.5	2.9	Within banks	155	160
	c. 285 m.ü.A. Breach Elev.	BREZICE	735	240	140	380	2.8	0.5	3.3	Within banks	100	115
	d. 290 m.ü.A. Water Elev.	ZAGREB	700	250	130	380	3.0	0.4	3.4	Within banks	210	215
		RUGVICA	664	280	120	400	4.1	1.0	5.1	Within banks	150	160
		STARA-GRADIŠKA	460	800	85	885	6.4	0.3	6.7	Within banks	190	195
		BRCKO	225	1100	50	1150	7.9	0.1	8.0	Bankfull	280	280
9	a. LJUBLJANA Barrier Breach	LJUBLJANA	852	50	1950	2000	-	-	-	-	-	-
	b. Complete removal	LITIJA	813	185	1770	1955	2.4	4.8	7.2	2.0	155	230
	c. 285 m.ü.A. Stream-bed	BREZICE	735	240	1550	1790	2.8	3.2	6.0	-	100	180
	d. 295 m.ü.A. Water Elev.	ZAGREB	700	250	1420	1670	3.0	3.4	6.4	1.5	210	240
		RUGVICA	664	280	1330	1610	4.1	6.5	10.6	-	150	240
		STARA-GRADIŠKA	460	800	880	1600	6.4	2.9	9.3	0.5	190	210/1000(3)
		BRCKO	225	1100	500	1600	7.9	1.1	9.0	1.0	280	290
10	a. LJUBLJANA Barrier Breach	LJUBLJANA	852	50	450	500	-	-	-	-	-	-
	b. Complete removal	LITIJA	813	185	380	665	2.4	1.4	3.8	Within banks	155	175
	c. 285 m.ü.A. Stream-bed	BREZICE	735	240	330	570	2.8	1.2	4.0	Within banks	100	130
	d. 290 m.ü.A. Water Elev.	ZAGREB	700	250	300	550	3.0	1.1	4.1	Within banks	210	220
		RUGVICA	664	280	270	550	4.1	2.0	6.1	Within banks	150	180
		STARA-GRADIŠKA	460	800	160	960	6.4	0.6	7.0	Within banks	190	200
		BRCKO	225	1100	90	1190	7.9	0.2	8.1	Bankfull	280	285
11	a. DOLSKO GORGE Barrier Breach	DOLSKO GORGE	832	-	[illegible]	10500	-	-	-	-	-	-
	b. 100 m. wide	LITIJA	813	185	7015	7200	2.4	(over 9.5)	(over 12)	(over 7)	155	(over 300)
	c. 265 m.ü.A. Breach Elev.	BREZICE	735	240	4660	4900	2.8	6.3	9.1	-	100	450
	d. 260 m.ü.A. Water Elev.	ZAGREB	700	250	3900	4150	3.0	6.6	9.6	4.5	210	450
		RUGVICA	664	280	3320	3600	4.1	10.6	14.7	7.5	150	300/5000(3)
		STARA-GRADIŠKA	460	800	1500	2300	6.4	4.0	10.4	1.5	190	220/2000(3)
		BRCKO	225	1100	700	1800	7.9	1.6	9.5	1.5	280	290

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TABLE 7
SUMMARY OF EFFECTS OF ARTIFICIAL FLOOD WAVES AND FLOW VARIATIONS (Continued)

	Location	River Km.	Discharge Initial m^3/sec	Discharge Increase m^3/sec	Discharge Crest m^3/sec	River Depth Initial m	River Depth Increase m	River Depth Crest m	Overflow(1) m	River Width Initial m	River Width Crest m	Mean Surface Velocity Initial m/sec	Mean Surface Velocity Crest m/sec	Time from Dam to Start Hours	Time from Dam to Crest Hours	Duration of Rise(2) Days
Breach	LJUBLJANA	852	50	675	725	-	-	-	-	-	-	-	-	0	0	24
	LITIJA	813	185	630	815	2.4	1.9	4.3	Bankfull	155	170	1.7	2.6	2	14	25
Elev.	BREZICE	735	240	570	810	2.8	1.6	4.4	Bankfull	100	140	1.8	2.4	6	36	25
Elev.	ZAGREB	700	250	530	780	3.0	1.7	4.7	Bankfull	210	220	0.8	1.8	10	42	26
	RUGVICA	664	280	500	780	4.1	3.4	7.5	Bankfull	150	200	0.8	0.9	14	51	26
	STARA-GRADIŠKA	460	800	340	1140	6.4	2.7	9.1	0.5	190	210/1000(3)	0.8	1.1	48	135	28
	BRCKO	225	1100	200	1300	7.9	0.4	8.3	0.5	280	285	0.6	0.7	96	172	30
Breach	LJUBLJANA	852	50	175	225	-	-	-	-	-	-	-	-	0	0	6
	LITIJA	813	185	165	350	2.4	0.5	2.9	Within banks	155	160	1.7	2.0	2	15	7
Elev.	BREZICE	735	240	140	380	2.8	0.5	3.3	Within banks	100	115	1.8	2.0	8	42	7
Elev.	ZAGREB	700	250	130	380	3.0	0.4	3.4	Within banks	210	215	0.8	1.1	11	48	7
	RUGVICA	664	280	120	400	4.1	1.0	5.1	Within banks	150	160	0.8	0.9	16	57	7
	STARA-GRADIŠKA	460	800	85	885	6.4	0.3	6.7	Within banks	190	195	0.8	0.9	60	125	8
	BRCKO	225	1100	50	1150	7.9	0.1	8.0	Bankfull	280	280	0.6	0.6	108	196	9
Breach	LJUBLJANA	852	50	1950	2000	-	-	-	-	-	-	-	-	0	0	10
	LITIJA	813	185	1770	1955	2.4	4.8	7.2	2.0	155	230	1.7	3.0	2	12	11
ed	BREZICE	735	240	1550	1790	2.8	3.2	6.0	-	100	180	1.8	2.7	5	30	11
lev.	ZAGREB	700	250	1420	1670	3.0	3.4	6.4	1.5	210	240	0.8	2.5	8	36	12
	RUGVICA	664	280	1330	1610	4.1	6.5	10.6	-	150	240	0.8	1.1	12	45	12
	STARA-GRADIŠKA	460	800	880	1680	6.4	2.9	9.3	0.5	190	210/1000(3)	0.8	1.1	42	108	13
	BRCKO	225	1100	500	1600	7.9	1.1	9.0	1.0	280	290	0.6	0.7	90	154	15
reach	LJUBLJANA	852	50	450	500	-	-	-	-	-	-	-	-	0	0	3
	LITIJA	813	185	380	665	2.4	1.4	3.8	Within banks	155	175	1.7	2.4	2	13	4
ed	BREZICE	735	240	330	570	2.8	1.2	4.0	Within banks	100	130	1.8	2.2	7	39	4
ev.	ZAGREB	700	250	300	550	3.0	1.1	4.1	Within banks	210	220	0.8	1.5	11	45	4
	RUGVICA	664	280	270	550	4.1	2.0	6.1	Within banks	150	180	0.8	0.9	15	54	5
	STARA-GRADIŠKA	460	800	160	960	6.4	0.6	7.0	Within banks	190	200	0.8	0.9	54	119	6
	BRCKO	225	1100	90	1190	7.9	0.2	8.1	Bankfull	280	285	0.6	0.6	102	180	6
Breach	DOLGIC OGROE	832	-	[illegible]	10500	-	-	-	-	-	-	-	-	0	0	1
	LITIJA	813	185	7015	7200	2.4	(over 9.5)	(over 12)	(over 7)	155	(over 300)	1.7	(over 3)	1	7	2
lev.	BREZICE	735	240	4660	4900	2.8	6.3	9.1	-	100	450	1.8	3.0	4	25	2
ev.	ZAGREB	700	250	3900	4150	3.0	6.6	9.6	4.5	210	450	0.8	3.5	8	27	2
	RUGVICA	664	280	3320	3600	4.1	10.6	14.7	7.5	150	300/5000(3)	0.8	1.5	10	36	3
	STARA-GRADIŠKA	460	800	1500	2300	6.4	4.0	10.4	1.5	190	220/2000(3)	0.8	1.2	41	99	3
	BRCKO	225	1100	700	1800	7.9	1.6	9.5	1.5	280	290	0.6	0.8	90	145	4

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TABLE 7

SUMMARY OF EFFECTS OF ARTIFICIAL FLOOD WAVES AND FLOW VARIATIONS (Continued)

Artificial Flood No.	Type of Outflow	Location	River Km.	Discharge Initial m³/sec	Discharge Increase m³/sec	Discharge Crest m³/sec	River Depth Initial m	River Depth Increase m	River Depth Crest m	Overflow(4) m	River Width Initial m	River Width Crest m
12	a. DOLSKO GORGE Barrier Breach	DOLSKO GORGE	832	-	1950	1950	-	-	-	-	-	-
	b. 100 m. wide	LITIJA	813	185	1315	1500	2.4	3.8	6.2	1.0	155	200
	c. 265 m.ü.A. Breach Elev.	BREZICE	735	240	960	1200	2.8	2.3	5.1	[illegible]	100	150
	d. 270 m.ü.A. Water Elev.	ZAGREB	700	250	800	1050	7.0	2.3	5.3	0.5	210	230
		RUGVICA	664	280	720	1090	4.1	4.2	8.5	1.5	150	210
		STARA-GRADIŠKA	460	800	300	1100	6.4	1.1	7.5	Bankfull	190	200
		BRČKO	225	1100	100	1200	7.9	0.2	8.1	Bankfull	290	280
13	a. DOLSKO GORGE Barrier Breach	DOLSKO GORGE	832	-	20300	20300	-	-	-	-	-	-
	b. 200 m. wide	LITIJA	813	185	11115	11300	2.4	(over 9.5)	(over 12)	(over 7)	155	(over 300)
	c. 265 m.ü.A. Breach Elev.	BREZICE	735	240	6410	6650	2.8	7.9	10.7	-	100	600
	d. 280 m.ü.A. Water Elev.	ZAGREB	700	250	5200	5450	3.0	8.4	11.4	6.5	210	550/2000(3)
		RUGVICA	664	280	4920	5200	4.1	11.6	15.7	8.5	150	300/5000(3)
		STARA-GRADIŠKA	460	800	1700	2500	6.4	4.3	10.7	2.0	190	230/2000(3)
		BRČKO	225	1100	800	1900	7.9	1.7	9.6	1.5	280	290
14	a. DOLSKO GORGE Barrier Breach	DOLSKO GORGE	832	-	3850	3850	-	-	-	-	-	-
	b. 200 m. wide	LITIJA	813	155	2315	2500	2.4	5.8	8.2	3.0	155	250
	c. 265 m.ü.A. Breach Elev.	BREZICE	735	240	1410	1650	2.8	3.0	5.8	-	100	170
	d. [illegible] m.ü.A. Water Elev.	ZAGREB	700	250	1100	1350	3.0	2.8	5.8	1.0	210	230
		RUGVICA	664	280	870	1150	4.1	5.0	9.1	2.0	150	220
		STARA-GRADIŠKA	460	800	350	1150	6.4	1.3	7.7	Bankfull	190	200
		BRČKO	225	1100	100	1200	7.9	0.7	8.6	6.5	280	290
15	a. MOSTE DAM Outlet Discharge	MOSTE DAM	904	15	93	108	-	-	-	-	-	-
	b. 5.1 m. Outlet Tunnel	OTOČE	885	55	[illegible]	134	2.0	0.5	2.5	Within banks	75	80
	c. (See plates 7 & 19)	SMLEDNIK	861	60	71	131	0.6	0.4	1.0	Within banks	70	90
	d. 514 m.ü.A. Water Elev.	LITIJA	813	185	63	248	2.4	0.2	2.6	Within banks	155	160
		BREZICE	735	240	53	293	2.8	0.2	3.0	Within banks	100	105
		ZAGREB	700	250	49	299	3.0	0.2	3.2	Within banks	210	215
16	a. MOSTE DAM Outlet Discharge	MOSTE DAM	904	15	110	125	-	-	-	-	-	-
	b. 5.1 m. Outlet Tunnel	OTOČE	885	55	100	155	2.0	0.6	2.6	Within banks	75	80
	c. (See plates 7 & 19)	SMLEDNIK	861	60	96	156	0.6	0.6	1.2	Within banks	70	95
	d. 523.5 m.ü.A. Water Elev.	LITIJA	813	185	91	276	2.4	0.3	2.7	Within banks	155	160
		BREZICE	735	240	83	323	2.8	0.3	3.1	Within banks	100	110
		ZAGREB	700	250	79	329	3.0	0.3	3.3	Within banks	210	215

*NOTES: See page 1, Table 7

TABLE 7

SUMMARY OF EFFECTS OF ARTIFICIAL FLOOD WAVES AND FLOW VARIATIONS (Continued)

	Location	River Km.	Discharge Initial m³/sec	Discharge Increase m³/sec	Discharge Crest m³/sec	River Depth Initial m	River Depth Increase m	River Depth Crest m	Overflow(1) m	River Width Initial m	River Width Crest m	Mean Surface Velocity Initial m/sec	Mean Surface Velocity Crest m/sec	Time from Dam to Start Hours	Time from Dam to Crest Hours	Duration of Rise Days(2)
r Breach	DOLSKO GOROE	832	-	1950	1950	-	-	-	-	-	-	-	-	0	0	1
	LITIJA	813	185	1315	1500	2.4	3.8	6.2	1.0	155	200	1.7	3.0	1	9	1
lev.	BREZICE	735	240	960	1200	2.8	2.3	5.1	[illegible]	100	150	1.8	2.5	5	27	1
ev.	ZAGREB	700	250	800	1050	7.0	2.3	5.3	0.5	210	230	0.8	2.1	9	33	2
	RUGVICA	664	280	720	1000	4.1	4.2	8.5	1.5	150	210	0.8	1.0	12	42	2
	STARA-GRADIŠKA	460	800	300	1100	6.4	1.1	7.5	Bankfull	190	200	0.8	0.9	45	105	2
	BRČKO	225	1100	100	1200	7.9	0.2	8.1	Bankfull	280	280	0.6	0.6	96	151	3
r Breach	DOLSKO GOROE	832	-	20300	20300	-	-	-	-	-	-	-	-	0	0	1
	LITIJA	813	185	11115	11300	2.4	(over 9.5)	(over 12)	(over 7)	155	(over 300)	1.7	(over 3)	1	6	1
lev.	BREZICE	735	240	6410	6650	2.8	7.9	10.7	-	100	600	1.8	3.0	3	23	2
ev.	ZAGREB	700	250	5200	5450	3.0	8.4	11.4	6.5	216	550/2000(3)	0.8	4.0	7	25	2
	RUGVICA	664	280	4920	5200	4.1	11.6	15.7	8.5	150	300/5000(3)	0.8	4.5	0	33	2
	STARA-GRADIŠKA	460	800	1700	2500	6.4	4.3	10.7	2.0	190	230/2000(3)	0.8	1.2	29	96	3
	BRČKO	225	1100	800	1900	7.9	1.7	9.6	1.5	280	290	0.6	0.8	87	142	4
r Breach	DOLSKO GOROE	832	-	3850	3850	-	-	-	-	-	-	-	-	0	0	1
	LITIJA	813	150	2315	2500	2.4	5.8	8.2	3.0	155	250	1.7	3.0	1	8	1
ev.	BREZICE	735	240	1410	1650	2.8	3.0	5.8	-	100	170	1.8	2.6	5	26	1
v.	ZAGREB	700	250	1100	1350	3.0	2.8	5.8	1.0	210	230	0.8	2.3	9	30	1
	RUGVICA	664	280	870	1150	4.1	5.0	9.1	2.0	150	220	0.8	1.1	11	39	1
	STARA-GRADIŠKA	460	800	350	1150	6.4	1.3	7.7	Bankfull	190	200	0.8	0.9	43	102	2
	BRČKO	225	1100	100	1200	7.9	0.7	8.6	6.5	280	290	0.6	0.7	93	148	3
charge	MOSTE DAM	904	15	93	108	-	-	-	-	-	-	-	-	0	0	1/2
	OTOČEC	885	55	[illegible]	134	2.0	0.5	2.5	Within banks	75	80	1.6	2.1	2	6	1/2
	SMLEDNIK	861	60	71	131	0.6	0.4	1.0	Within banks	70	90	1.5	2.0	4	10	1/2
v.	LITIJA	813	185	63	248	2.4	0.2	2.6	Within banks	155	160	1.7	1.8	9	16	1/2
	BREZICE	735	240	53	293	2.8	0.2	3.0	Within banks	100	105	1.8	1.9	17	26	3/4
	ZAGREB	700	250	49	299	3.0	0.2	3.2	Within banks	210	215	0.8	1.0	21	31	3/4
charge	MOSTE DAM	904	15	110	125	-	-	-	-	-	-	-	-	0	0	3/4
	OTOČEC	885	55	100	155	2.0	0.6	2.6	Within banks	75	80	1.6	2.2	2	9	1
	SMLEDNIK	861	60	96	156	0.6	0.6	1.2	Within banks	70	95	1.5	2.1	4	15	1
lev.	LITIJA	813	185	91	276	2.4	0.3	2.7	Within banks	155	160	1.7	1.9	9	21	1
	BREZICE	735	240	83	323	2.8	0.3	3.1	Within banks	100	110	1.8	1.9	17	32	1-3/4
	ZAGREB	700	250	79	329	3.0	0.3	3.3	Within banks	210	215	0.8	1.0	21	36	1-1/4

ble 7

Prepared by Military Hydrology R&D Branch
Washington Dist., Corps of Engineers

RESTRICTED
SECURITY INFORMATION

TABLE 8

LOAD CHARACTERISTICS OF U. S. ARMY FLOATING BRIDGES

LOAD CLASS (TONS) OF FLOATING BRIDGES (by VELOCITY, by TYPE, by RELATIVE CROSSING SAFETY

Type	Status (1952)	Relative Crossing Safety: Safe — Maximum Surface Velocity fps / m/sec						Caution — Maximum Surface Velocity fps / m/sec					Risk — Maximum Surface Velocity fps / m/sec					Velocity to destroy with no Load (fps)
		0	3	5	7	9	11	3	5	7	9	11	3	5	7	9	11	
		0	0.92	1.5	2.1	2.7	3.4	0.92	1.5	2.1	2.7	3.4	0.92	1.5	2.1	2.7	3.4	
M2 Assault Boat Bridge (Normal Construction)	Standard	8	8	6	5	-	-	8	6	5	-	-	9	7	6	-	-	10
M2 Assault Boat Bridge (Reinforced Construction)	Standard	13	13	9	7	-	-	13	11	8	-	-	14	12	9	-	-	9
Widened Steel Treadway Br.	Standard	50	50	50	40	30	15	50	50	45	35	20	55	55	50	45	30	14
50-T (Divisional Airborne)	Standard	50	45	35	30	10	-	50	40	35	15	-	55	50	45	25	-	12
M4 (Normal Construction) (15' Bay)	Standard	55	55	55	55	45	30	60	60	60	50	40	65	65	65	55	45	16
Steel Class 60 Floating Br.	Standard	60	60	60	55	50	15	65	65	60	55	30	75	75	70	65	45	-
M4 (Reinforced Construction) (7½' Bay)**	Standard	95*	95*	95*	95*	70	40	100*	100*	100*	85	55	105*	105*	105*	100	70	16
M4-T6	Developmental	55	50	50	50	35	15	(No further data)										-
Aluminum Class 60 Floating Br.	Developmental	70	70	70	65	55	45	(No further data)										

Prepared by Military Hydrology R&D Branch
Washington District, Corps of Engineers, Nov. 1952

*Tank data (limited by width of roadway and width of tank)
**(100% reinforced, with full Pontoons)

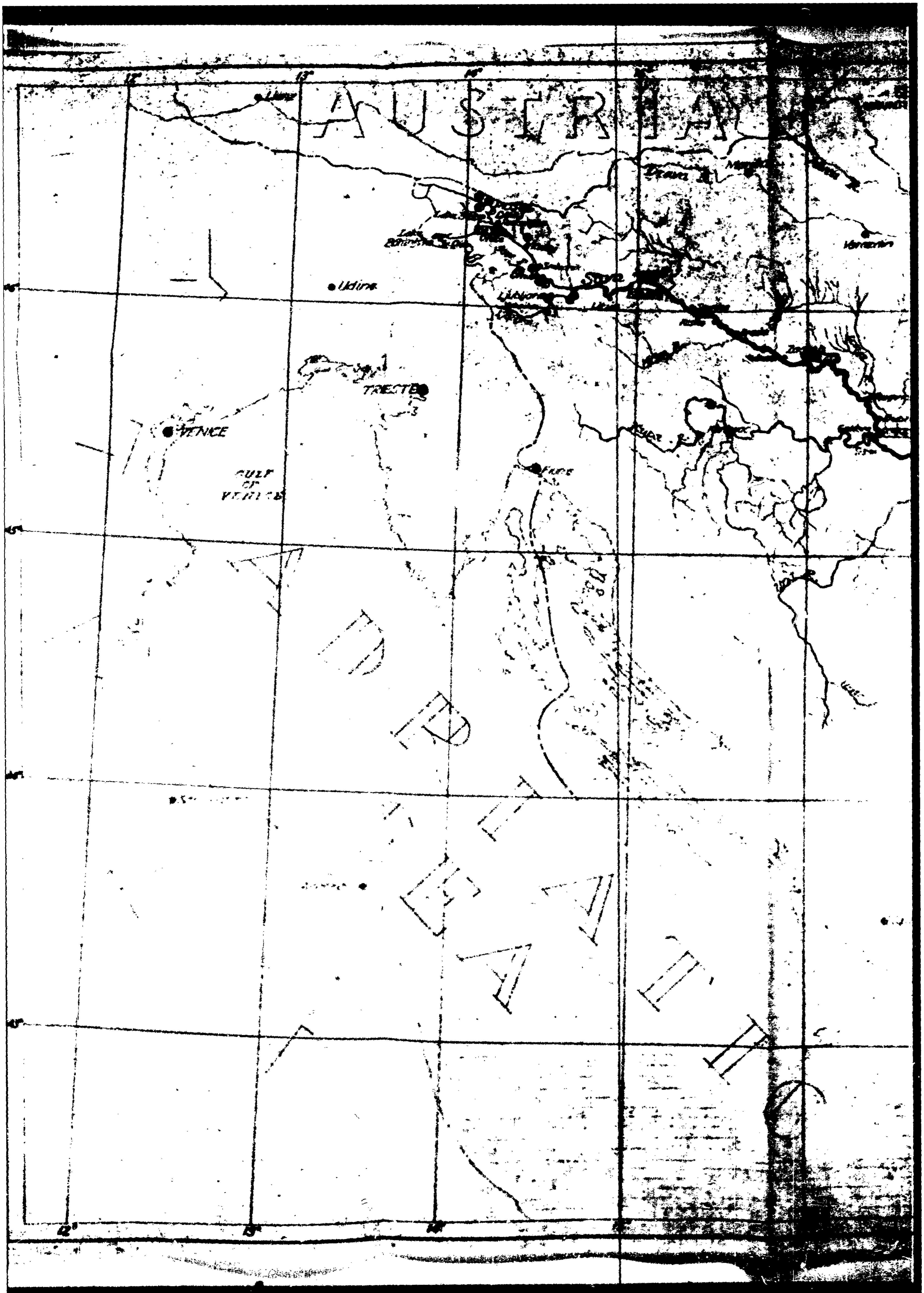
SOURCES:
(1) Ref 28
(2) Ref 28
(3) Misc data Engr. R&D Lab. Engr. Center, Ft. Belvoir

Table 8

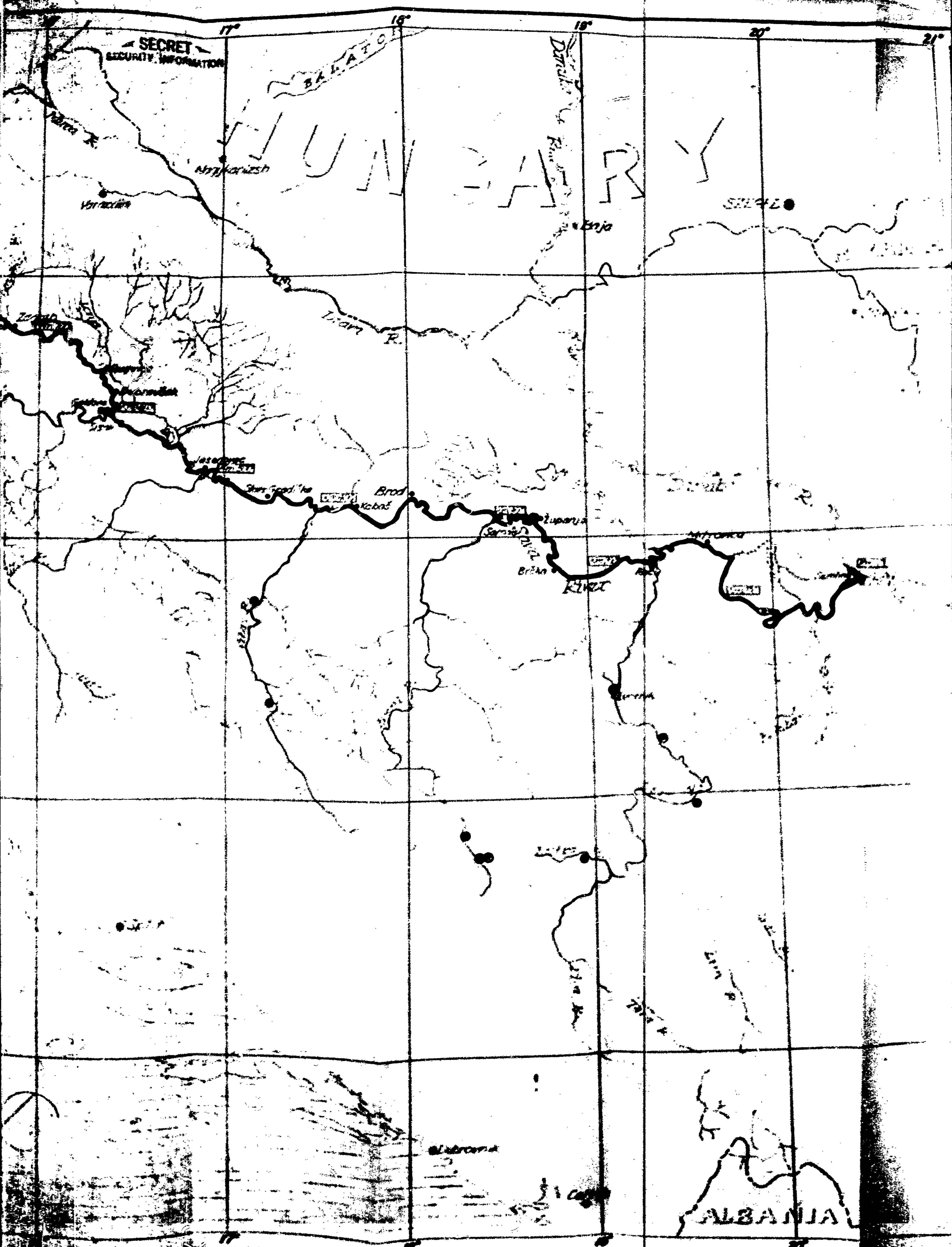
RESTRICTED
SECURITY INFORMATION

PLATES

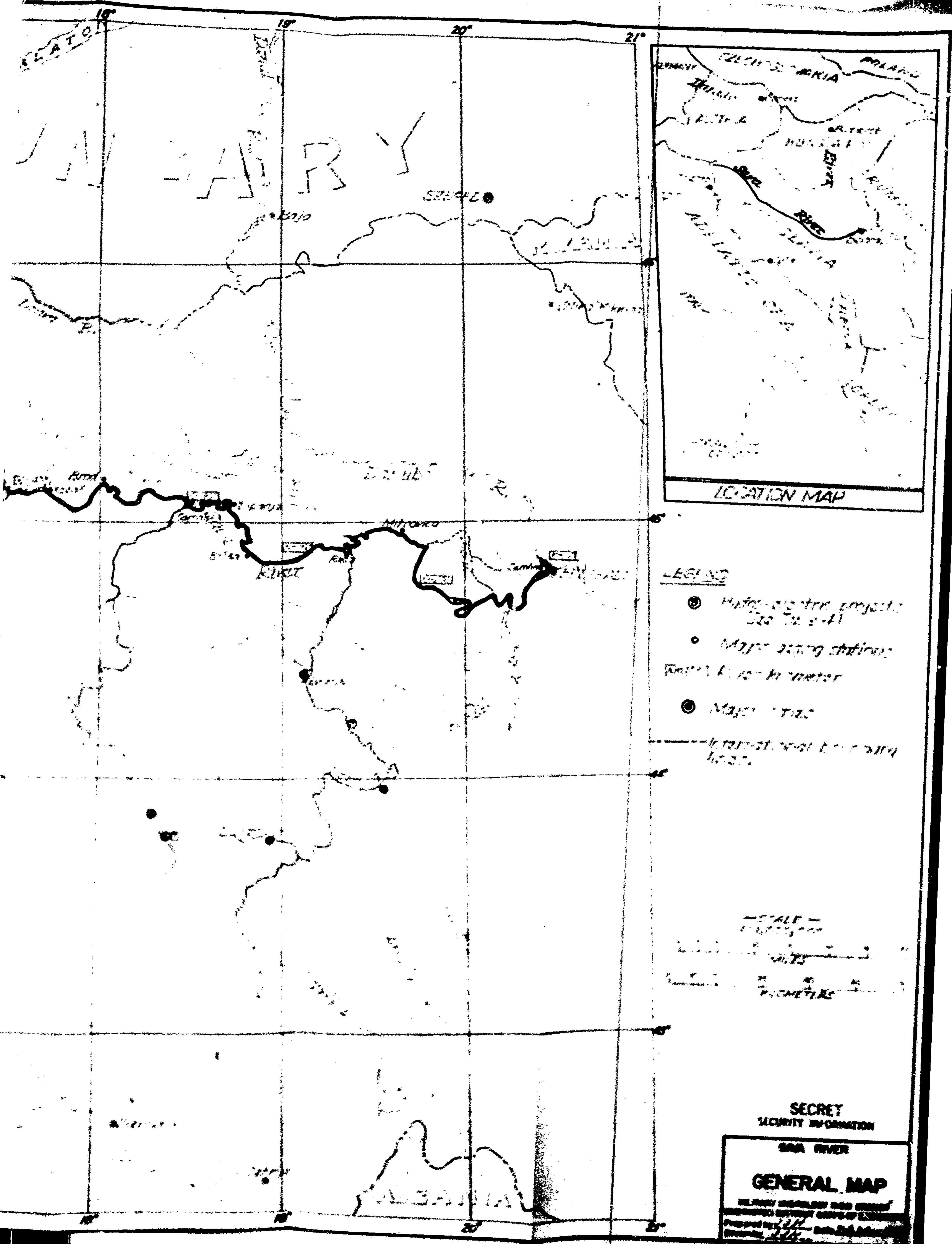
1. General Map
2. Physiographic Diagram
3. Drainage Pattern, JULIAN Region
4. Stream-Bed Profile, SAVA River
5. Stream-Bed Profile, LJUBLJANA River
6. Channel & Flood-Plain Widths
7. Sketches of MOSTE DAM
8. Bridge Locations, JESENICE-ZAGREB
9. Stage Variations
10. Monthly Mean Stages, SV. DUH-LJUBLJANA
11. Monthly Mean Stages, BREZICE-GALDOVA
12. Stage Duration Curves, SVETI DUH & VRHNIKA
13. Stage Duration Curves, LITIJA-SEVNICA
14. Discharge & Velocity Rating Curves, LJUBLJANA-LITIJA
15. Discharge & Velocity Rating Curves, ZAGORJE-RUGVICA
16. Discharge & Velocity Rating Curves, STARA GRADIŠKA-MITROVICA
17. Depth, Discharge & Velocity Profile
18. Inundation by Still-water Barriers
19. ~~MOSTE DAM, Reservoir Storage & Outlet Discharge~~
20. Discharge Hydrographs, MOSTE DAM, Artificial Floods 1-3
21. Discharge Hydrographs, MOSTE DAM, Artificial Floods 4-6
22. Discharge Hydrographs, LJUBLJANA Barrier, Artificial Floods 7-10
23. Discharge Hydrographs, DOLSKO GORGE Barrier, Artificial Floods 11-14
24. Discharge Hydrographs, MOSTE DAM, Artificial Floods 15 & 16

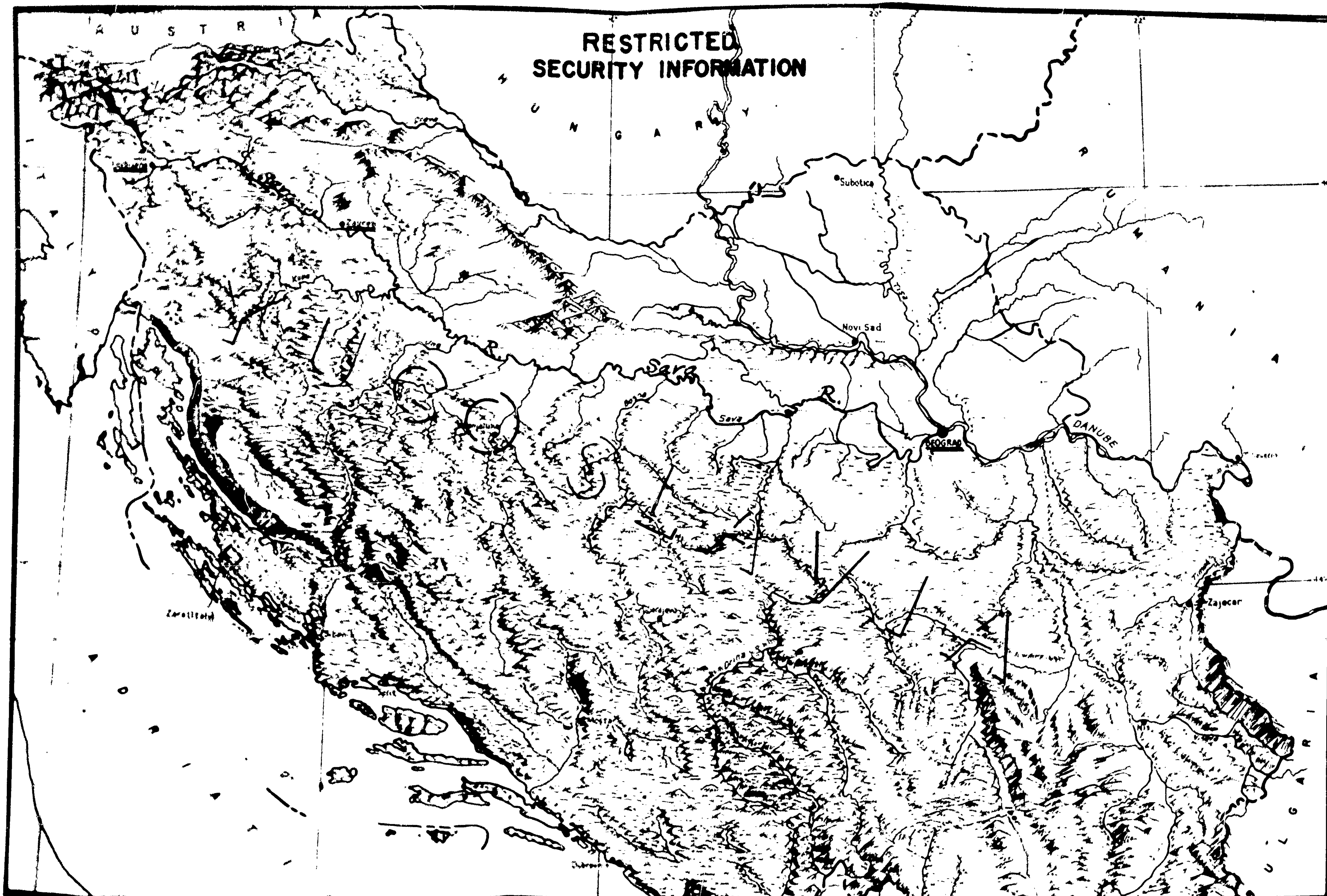


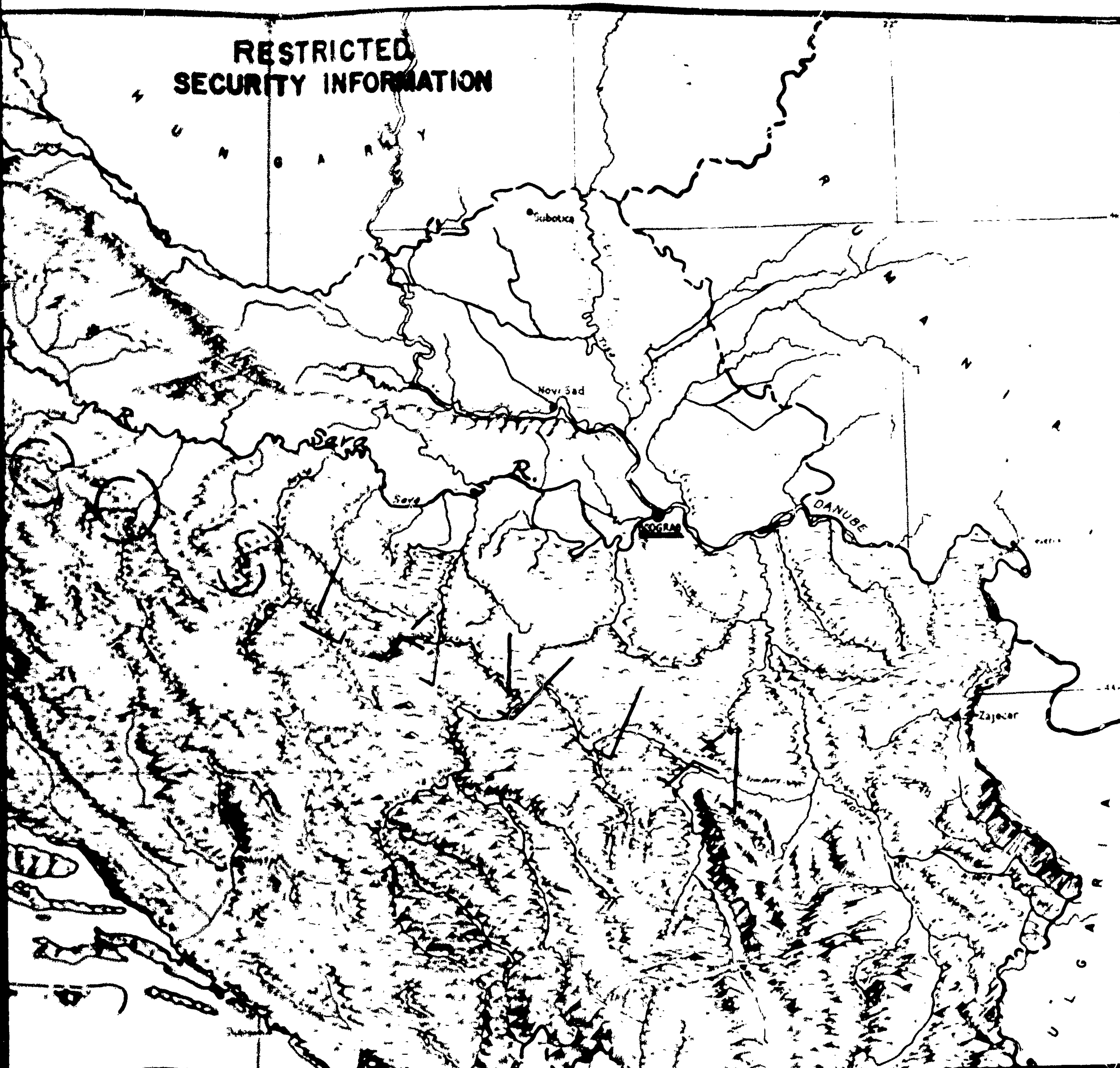
AUSTRIA
Udine
TRIESTE
VENICE
GULF OF VENICE



SECRET
SECURITY INFORMATION
17°
18°
19°
20°
21°
HUNGARY
Brod
Županja
Brčko
ALBANIJA


18°
19°
20°
21°
45°
LOCATION MAP
Mitrovica
LEGEND
SECRET
SECURITY INFORMATION
SAVA RIVER
GENERAL MAP


AUSTRIA
HUNGARY
RUMANIA
BULGARIA
ITALY
ADRIATIC
Subotica
Novi Sad
BEOGRAD
DANUBE
Sava R.
Sava
Zajecar
Zagreb



Topography generalized from contour maps; 1:1,000,000 series and from Yugoslavia 1:100,000 series. Vertical scale greatly exaggerated.

REPRODUCTION OF US GEOLOGICAL SURVEY DRAWING IN "S.E.S. NO. 82, YUGOSLAVIA, VOLUME 2, O.C.E., USA AUGUST 1943."

÷SCALE÷

10 5 0 10 20 30 40 50 60 Mi.

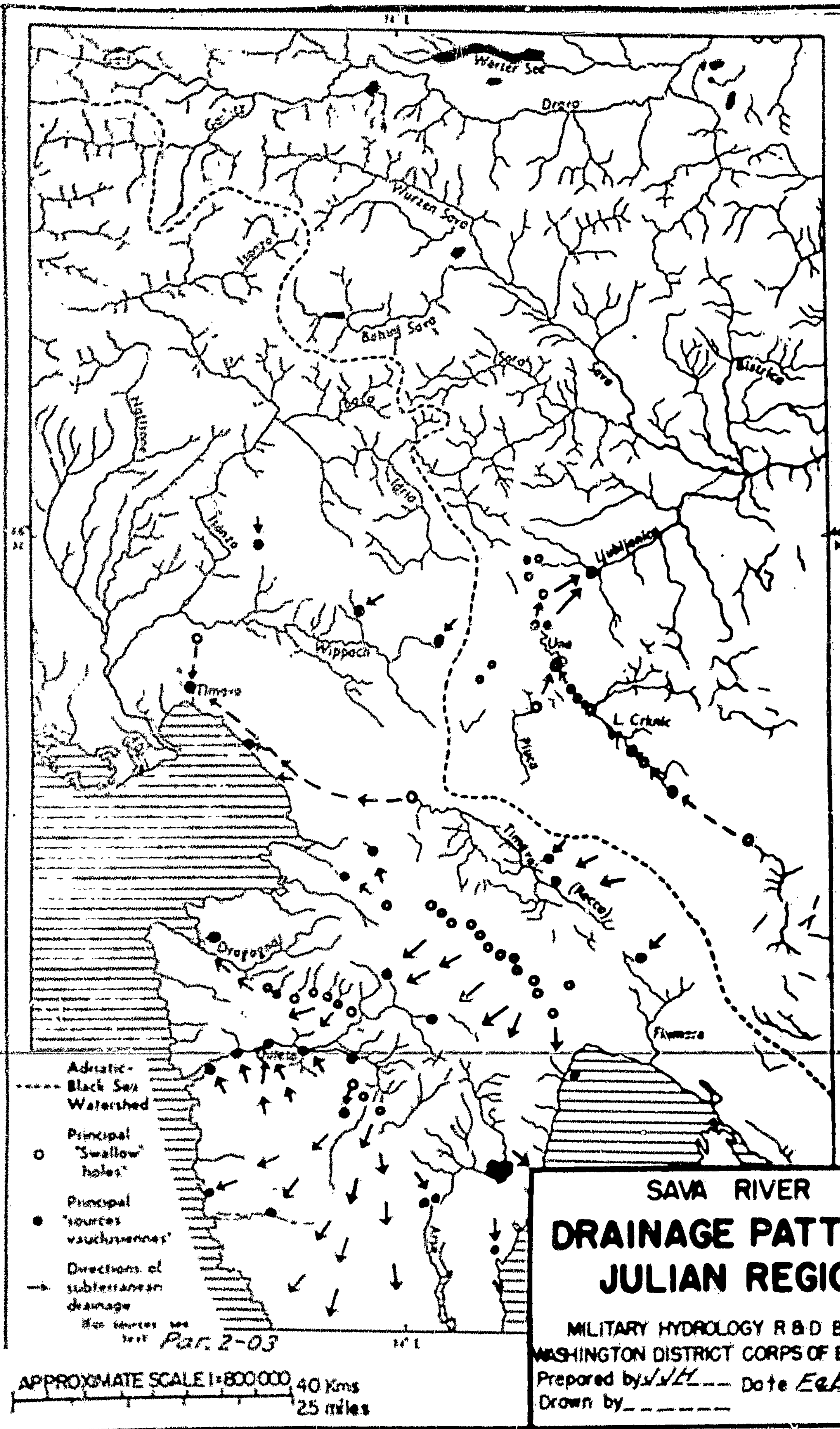
10 5 0 10 20 30 40 50 60 70 80 90 100 Km.

RESTRICED
SECURITY INFORMATION

SAVA RIVER
PHYSIOGRAPHIC DIAGRAM

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by J.J.H. Date Feb. 4, 1953
Drawn by ______

PLATE 2

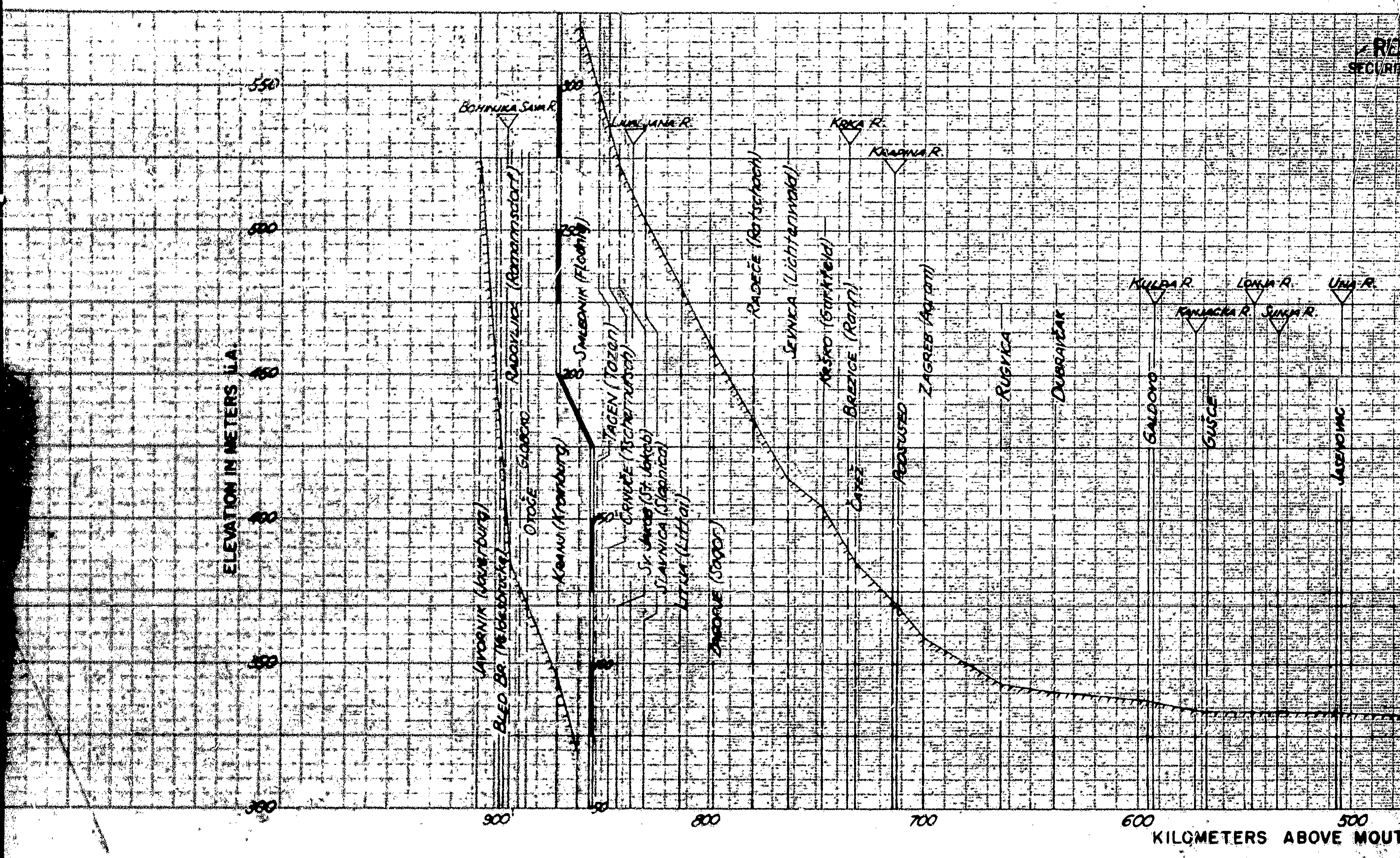


SAVA RIVER

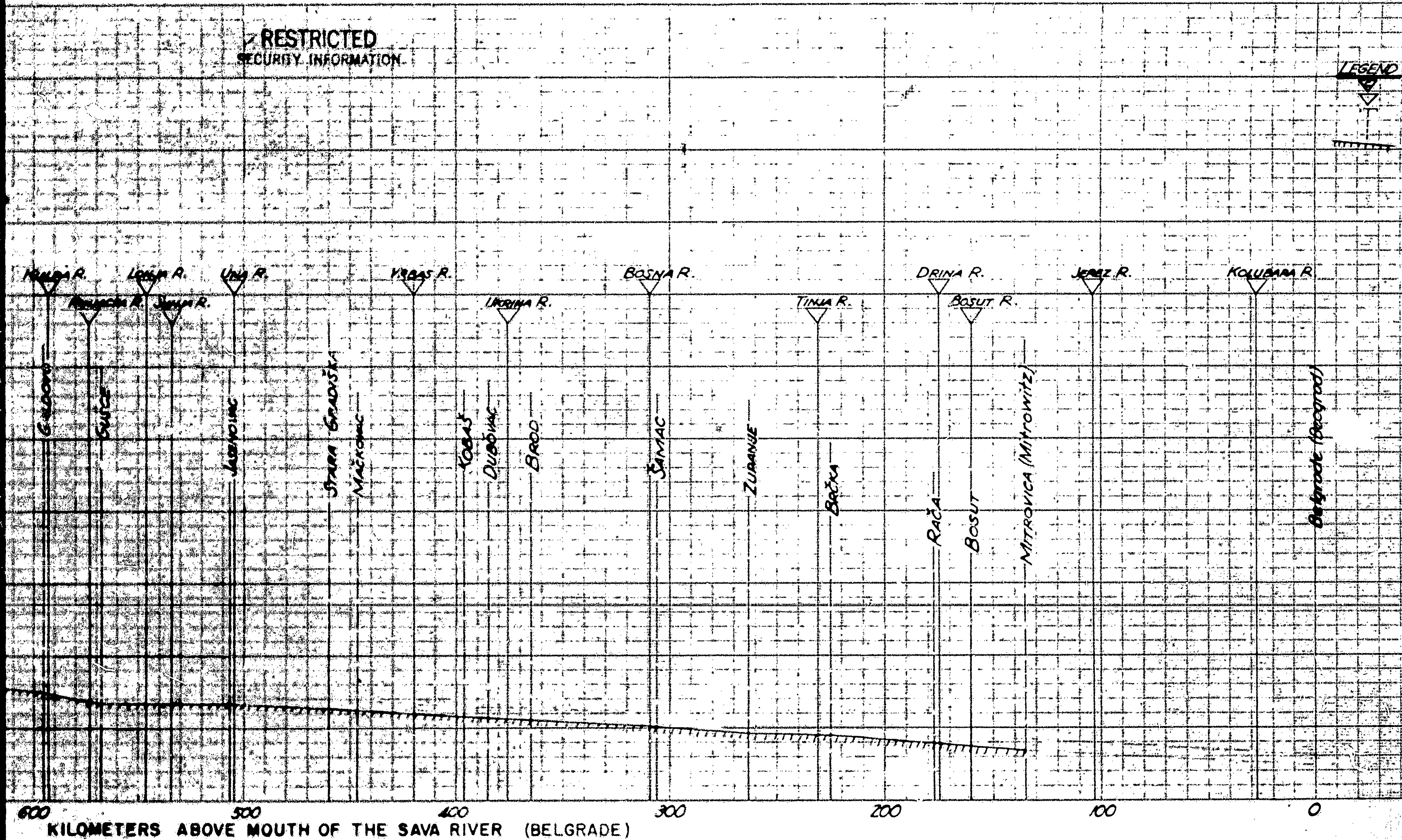
DRAINAGE PATTERN JULIAN REGION

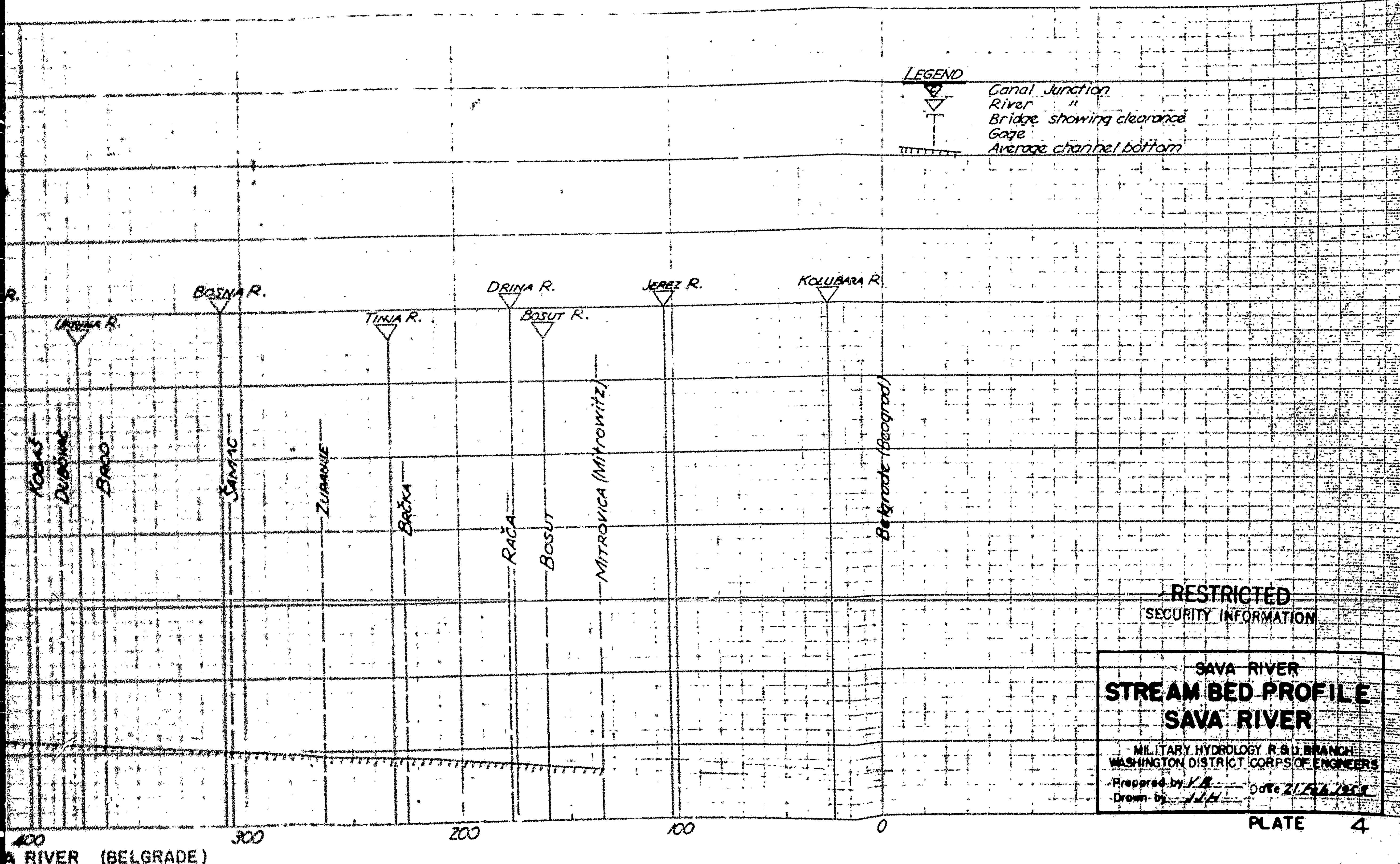
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by J.J.H. Date Feb 24, 1953
Drawn by______

PLATE 3



ELEVATION IN METERS U.A.
KILOMETERS ABOVE MOUT
550
500
450
400
350
300
900
800
700
600
500
BOHINJKA SAVA R.
LJUBLJANA R.
KRKA R.
KRAPINA R.
KULPA R.
KANJACKA R.
LONJA R.
SUNJA R.
UNA R.
JAVORNIK (Jauerburg)
BLED BR. (Veldesbrucke)
RADOVLJICA (Rammansdorf)
OTOČE
GLOBOKO
KRANJ (Kranburg)
SMLEDNIK (Flodnig)
TAGEN (Tozen)
ČRNUČE (Tschernutsch)
SV. JAKOB (St. Jakob)
SLAVNICA (Slapnica)
LITIJA (Littai)
ZAGORJE (Sagor)
RADEČE (Ratschach)
SEVNICA (Lichtenwald)
KRŠKO (Gurkfeld)
BREZICE (Rann)
ČATEŽ
PODSUSED
ZAGREB (Agram)
RUGVICA
DUBRAVČAK
GALDOVO
GUŠĆE
JASENOVAC


LEGEND
Kolubara R.
Drina R.
Bosut R.
Tinja R.
Bosna R.
Ukrina R.
Vrbas R.
Una R.
Lonja R.
Sunja R.
Belgrade (Beograd)
Mitrovica (Mitrowitz)
Bosut
Rača
Bačka
Županje
Šamac
Brod
Dubočac
Kobaš
Mačkovac
Stara Gradiška
Jasenovac
Gušće
600
500
400
300
200
100
0
KILOMETERS ABOVE MOUTH OF THE SAVA RIVER (BELGRADE)



RESTRICTED
SECURITY INFORMATION

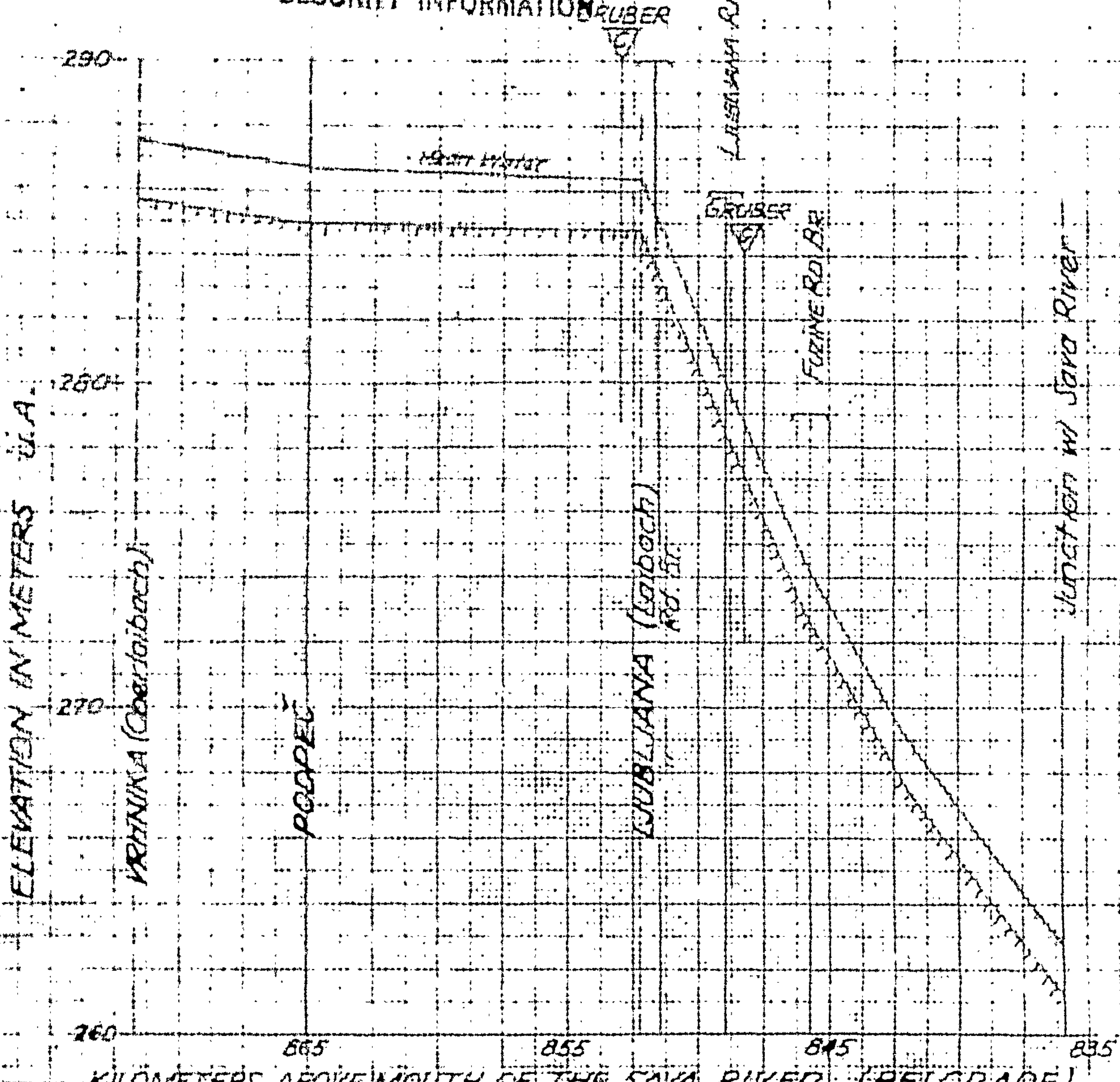
SAVA RIVER
STREAM BED PROFILE
SAVA RIVER

MILITARY HYDROLOGY R.&U. BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by V.B. Date 21 Feb. 1952
Drawn by J.J.H.

PLATE 4

RESTRICTED
SECURITY INFORMATION



LEGEND
See Plate 4

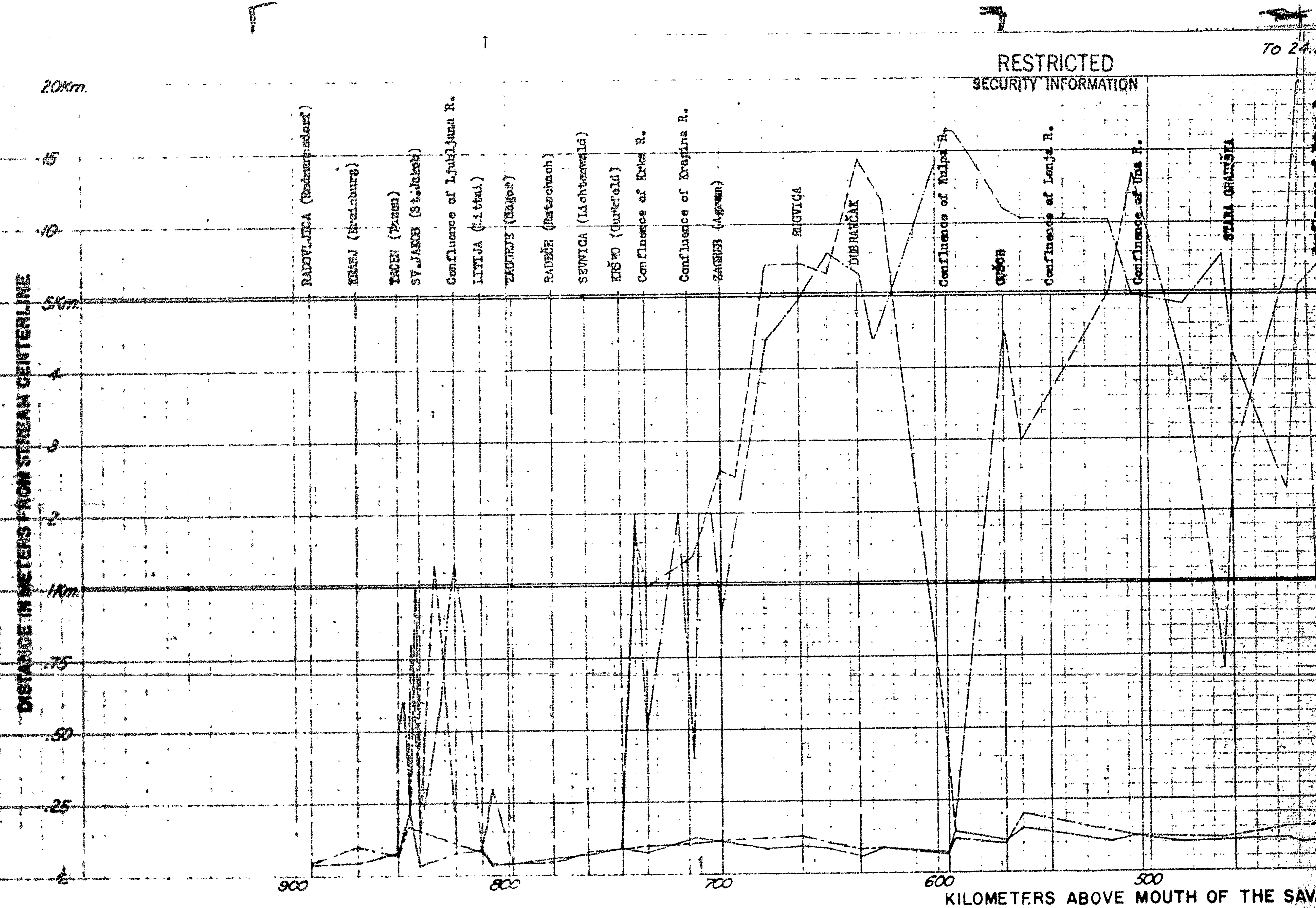
SAVA RIVER
STREAM BED PROFILE
LJUBLJANA RIVER

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by VB Date 12 Mar 1953
Drawn by

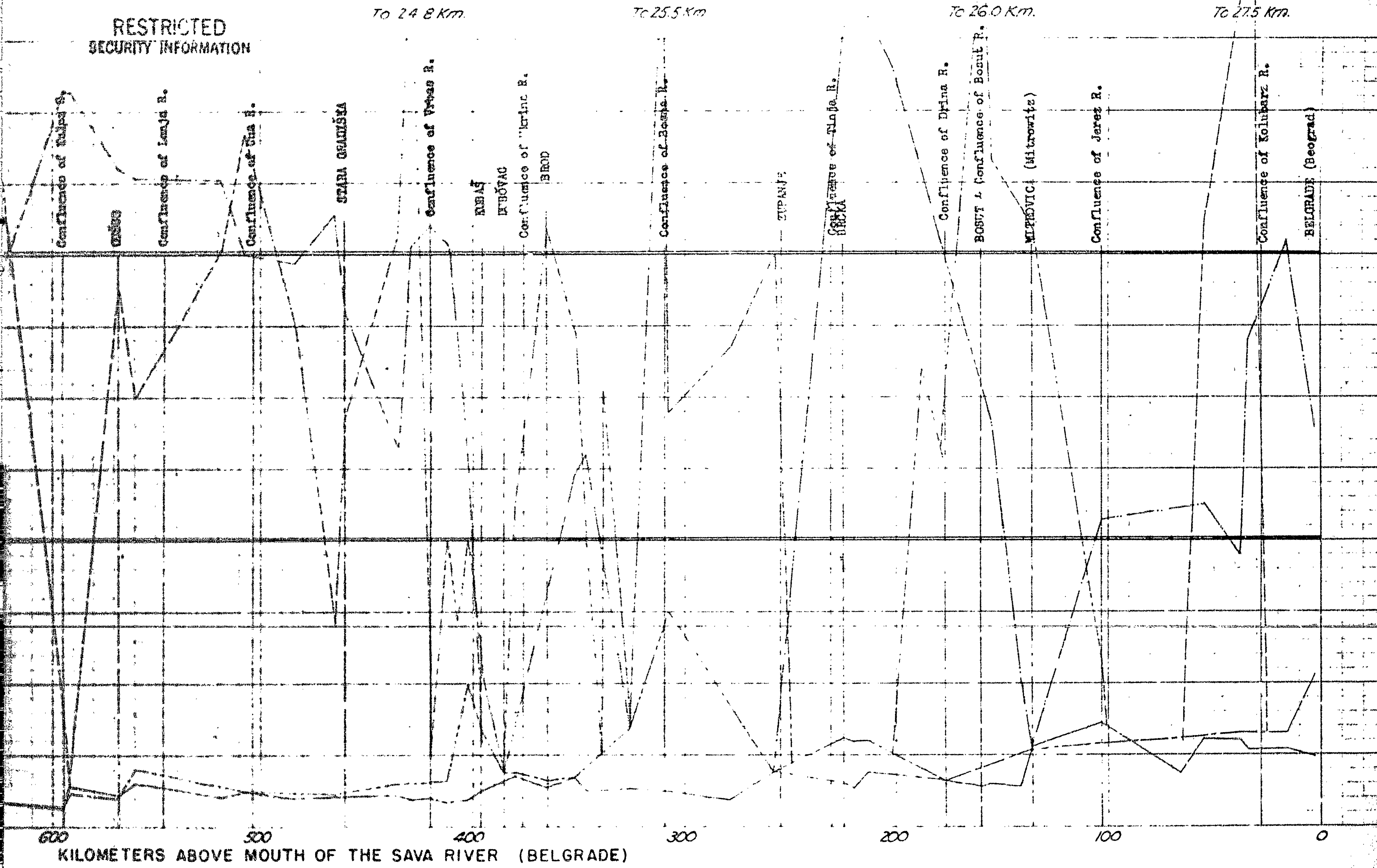
RESTRICTED
SECURITY INFORMATION

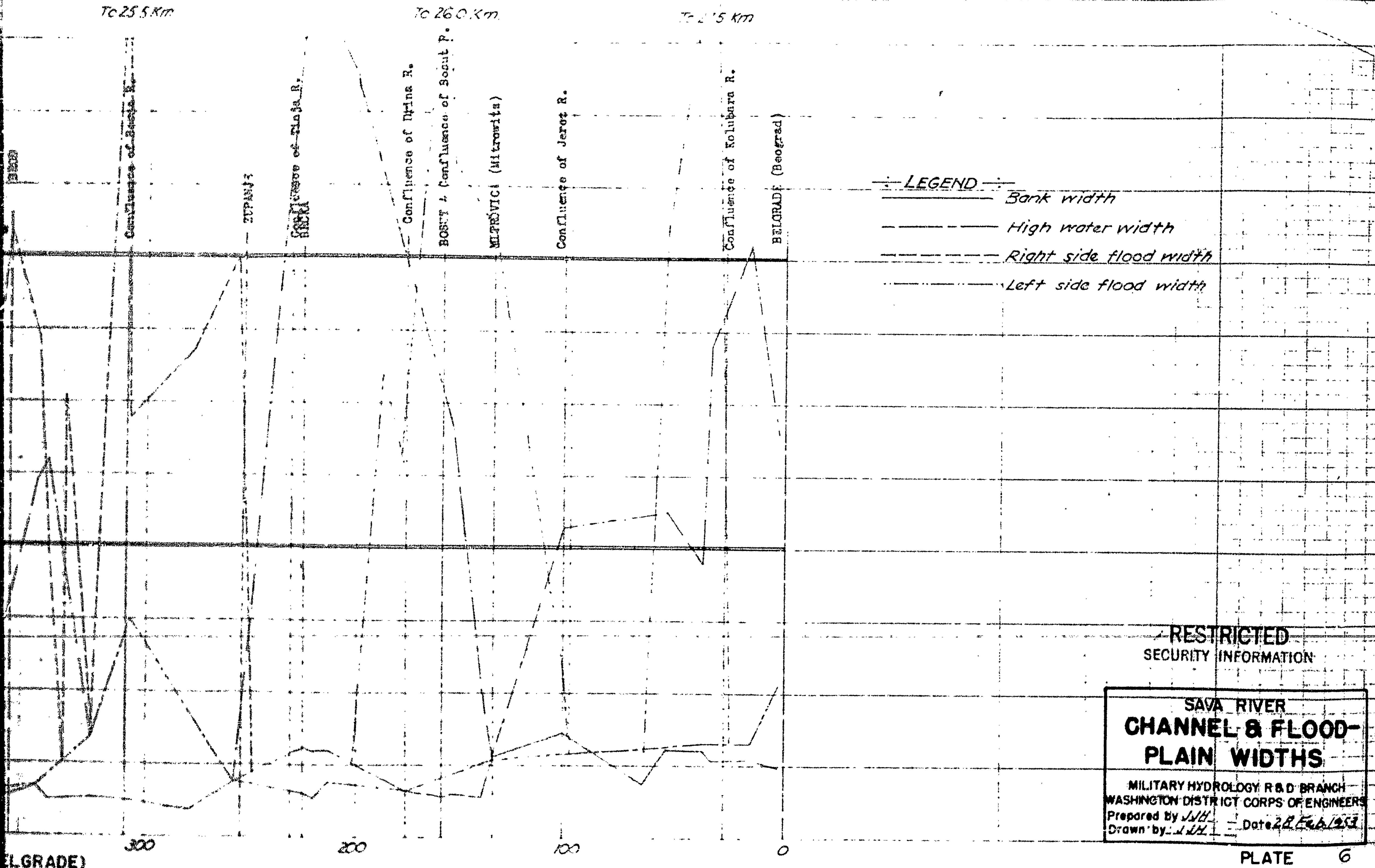
PLATE 5

RESTRICTED
SECURITY INFORMATION



RESTRICTED
SECURITY INFORMATION



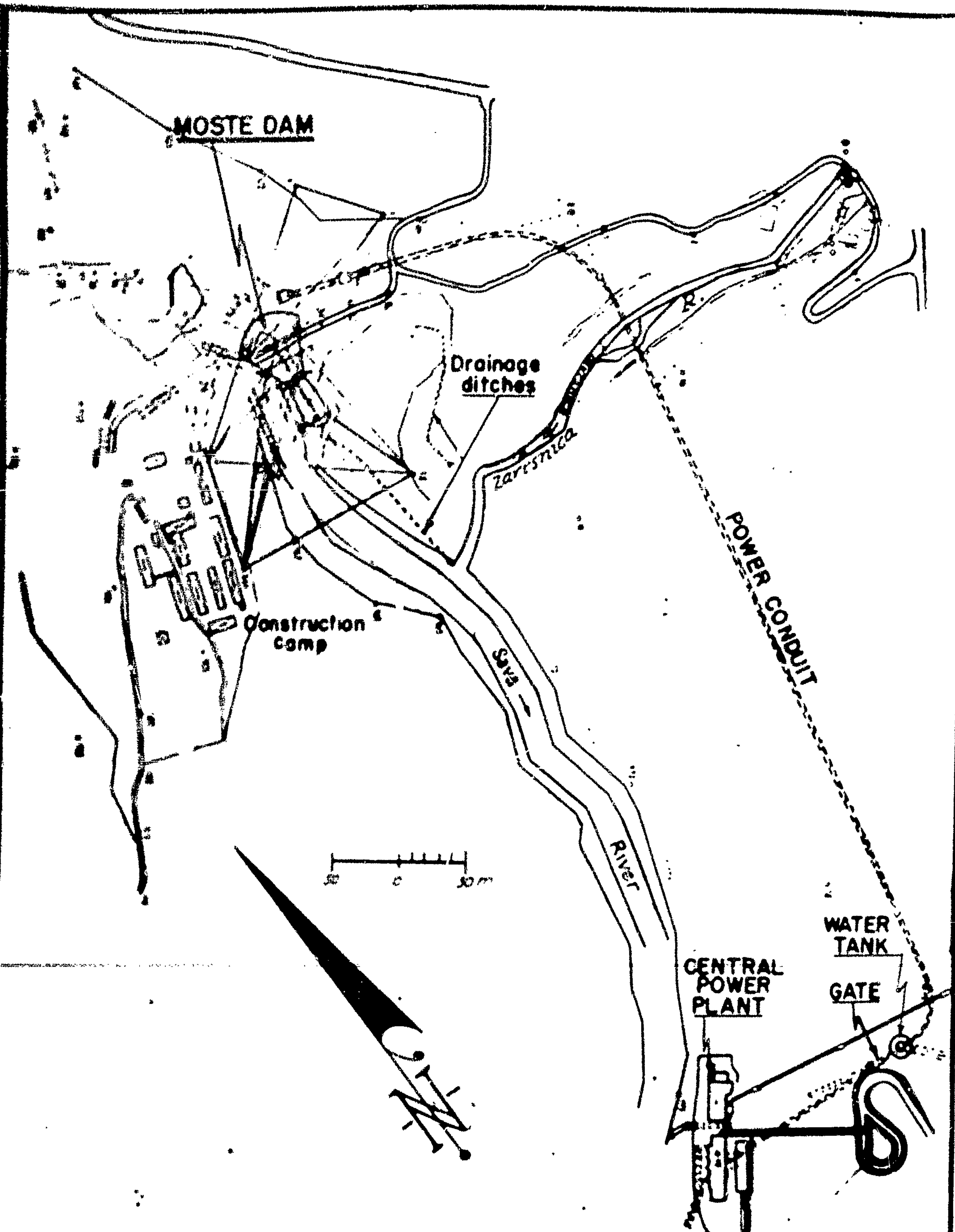


RESTRICTED
SECURITY INFORMATION

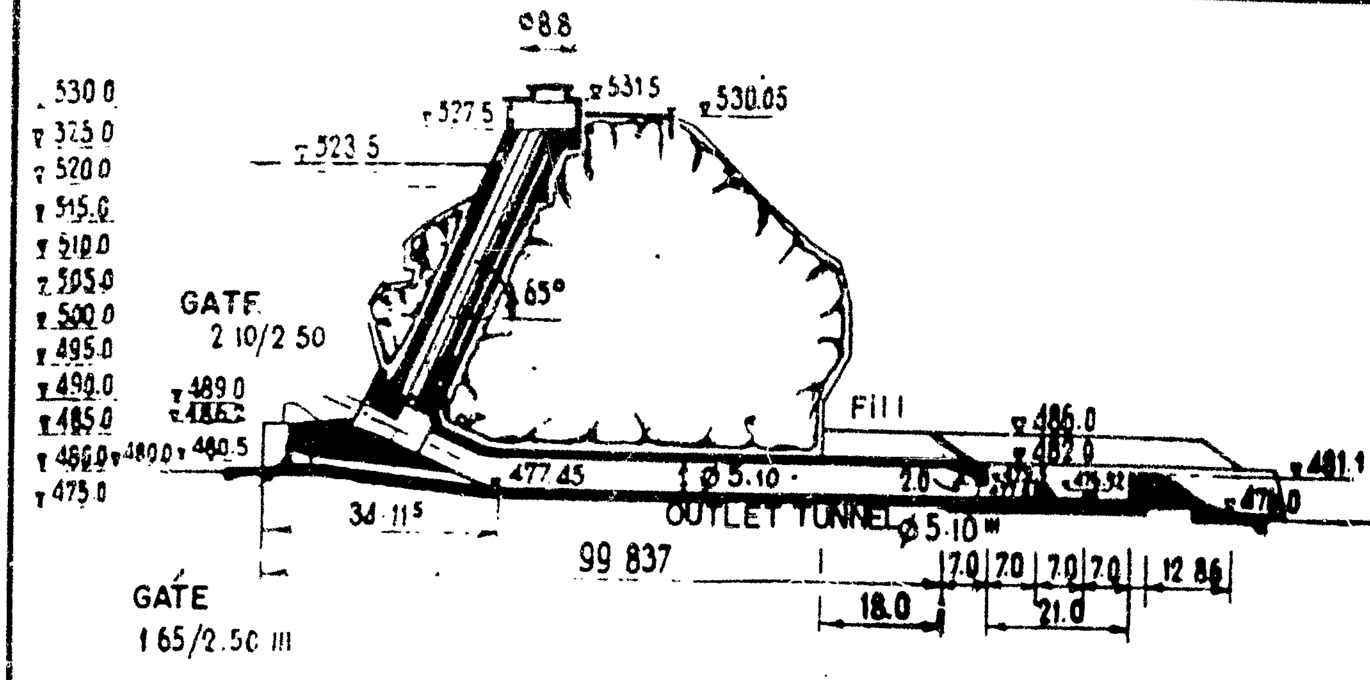
SAVA RIVER
CHANNEL & FLOOD-PLAIN WIDTHS

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by J.J.H. Date 28 Feb 1953
Drawn by J.J.H.

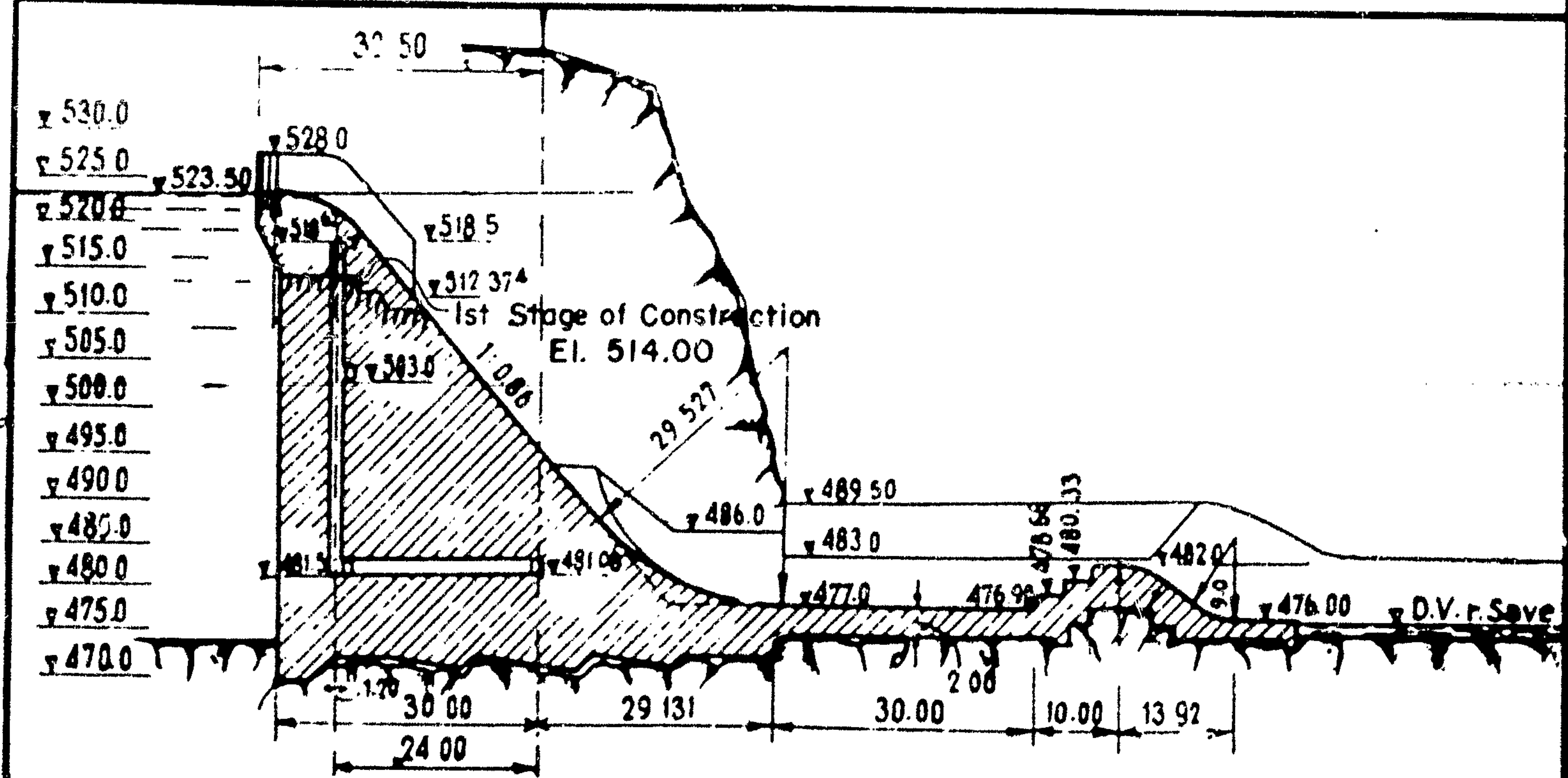
PLATE 6



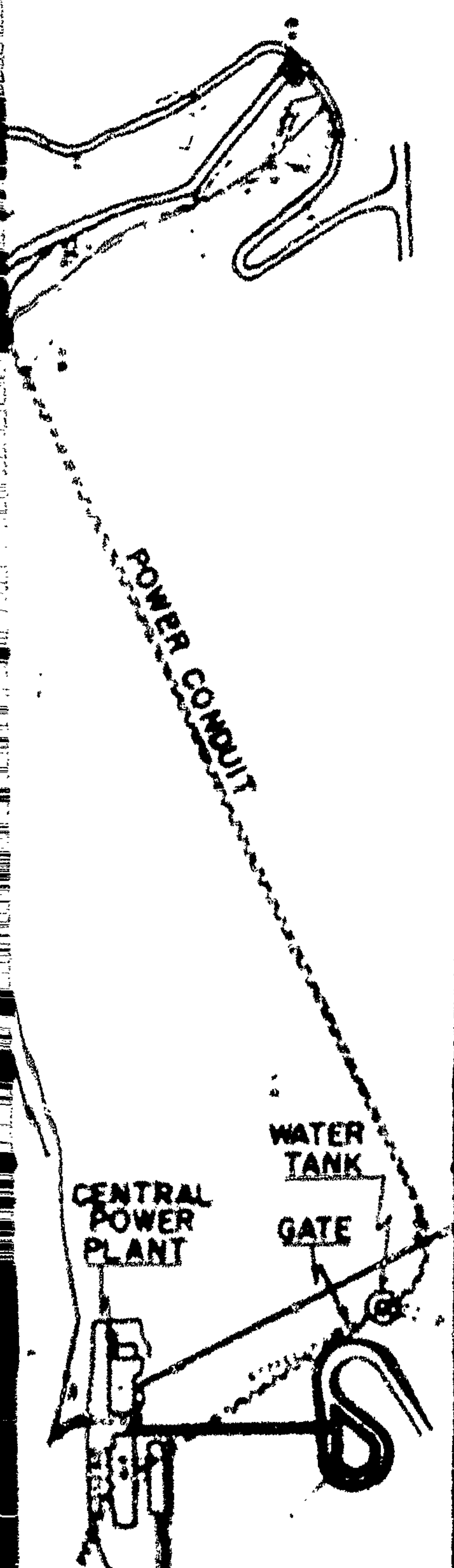
GENERAL PLAN OF DAMSITE
Fig. 1

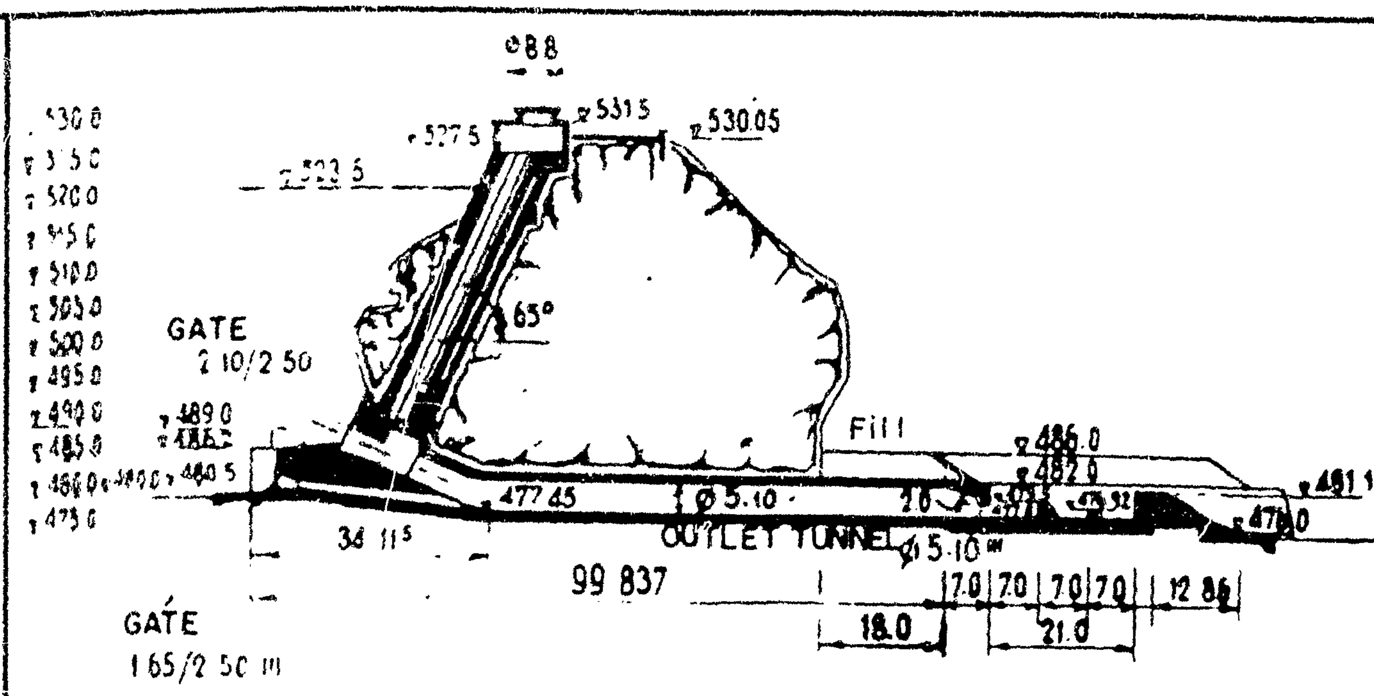


CROSS SECTION ALONG OUTLET
Fig. 2

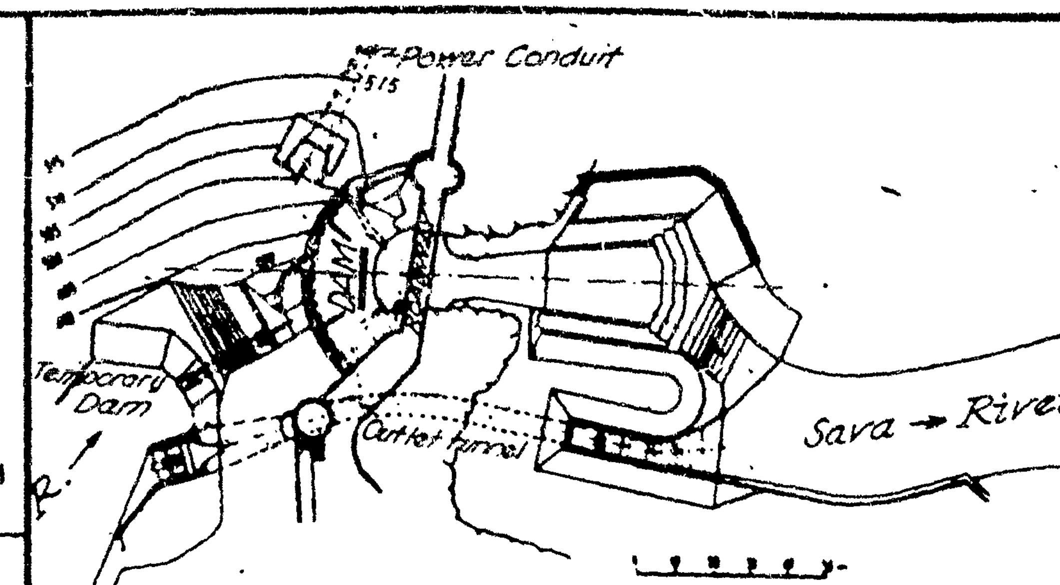


CROSS SECTION OF DAM
Fig. 4





CROSS SECTION ALONG OUTLET
Fig. 2

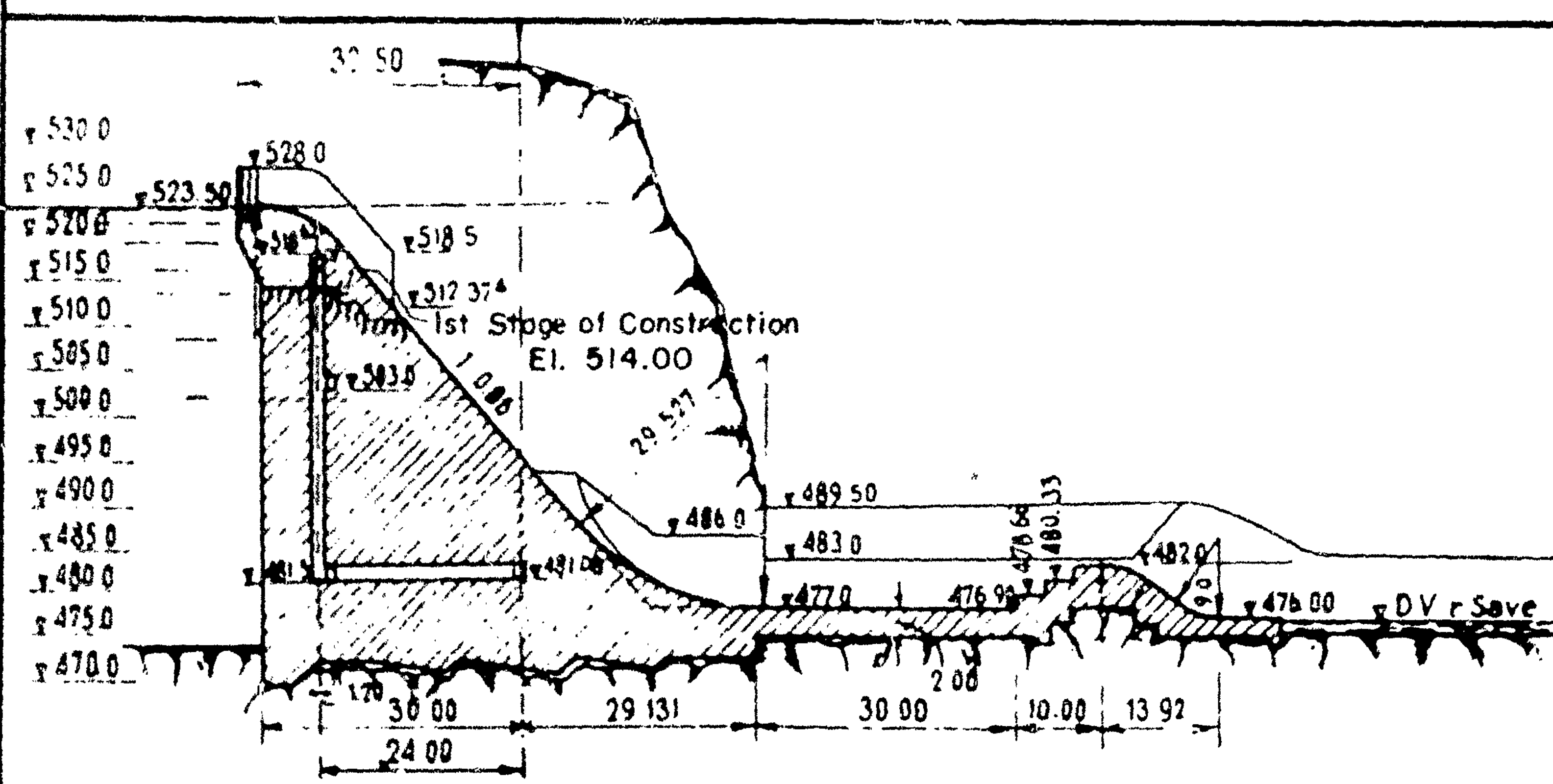


PLAN OF DAM AND OUTLETS
Fig. 3

SOURCE:
"SAOPŠTENJA, sa Prvog savetovanja stručnjaka Jugoslavije O Visokim Branama."

"TRANSACTIONS, The first meeting of the Yugoslav National Committee on Large Dams." (18-23 September 1950, Zagreb).

Fig. 1 — p 171
Fig 2 — p 44
Fig. 3 — p 43
Fig. 4 — p 44

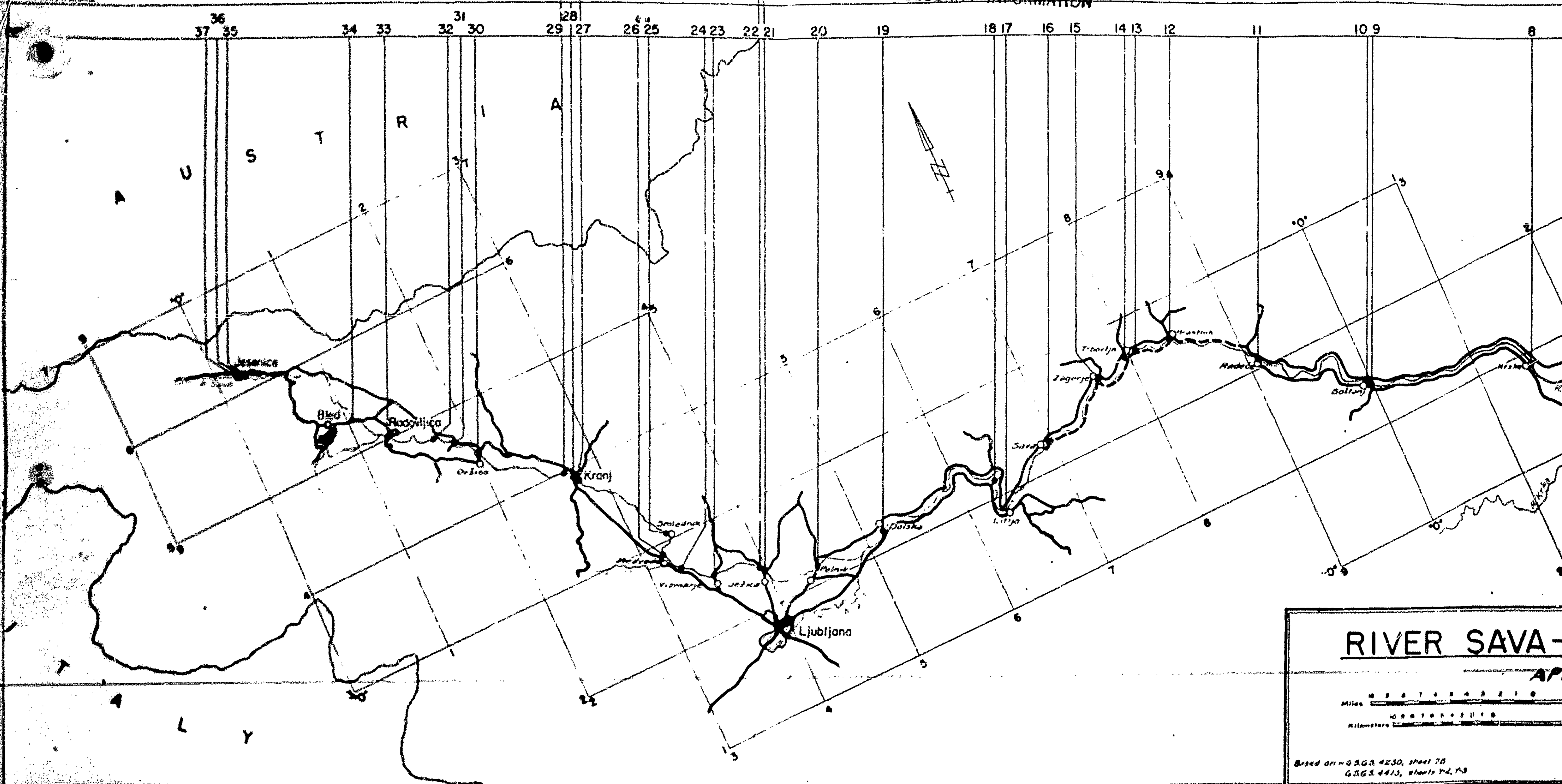


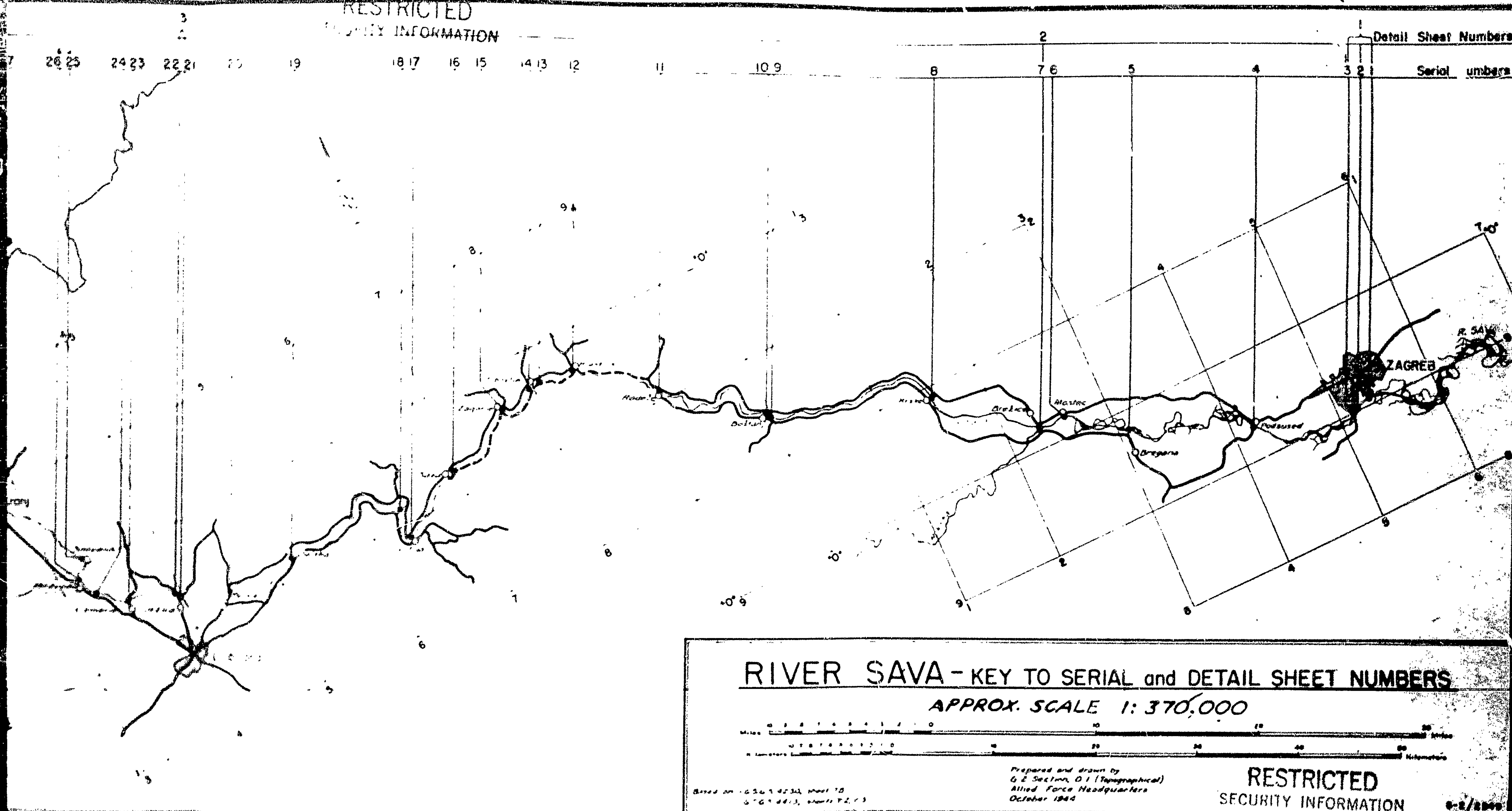
CROSS SECTION OF DAM
Fig. 4

SAVA RIVER
SKETCHES OF MOSTE DAM

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JJH Date 24 Feb 1953
Drawn by

PLATE 7


Sheet Numbers
37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8
4
3
AUSTRIA
ITALY
Jesenice
Bled
Radovljica
Kranj
Smlednik
Medvode
Vižmarje
Ježica
Ljubljana
Polje
Dolsko
Litija
Sava
Zagorje
Trbovlje
Hrastnik
Radeče
Boštanj
RIVER SAVA-
AP
Miles
Kilometers
Based on - G.S.G.S. 4250, sheet 7B
G.S.G.S. 4413, sheets T-4, T-5



SAVA RIVER

BRIDGE LOCATIONS

JESENICE–ZAGREB

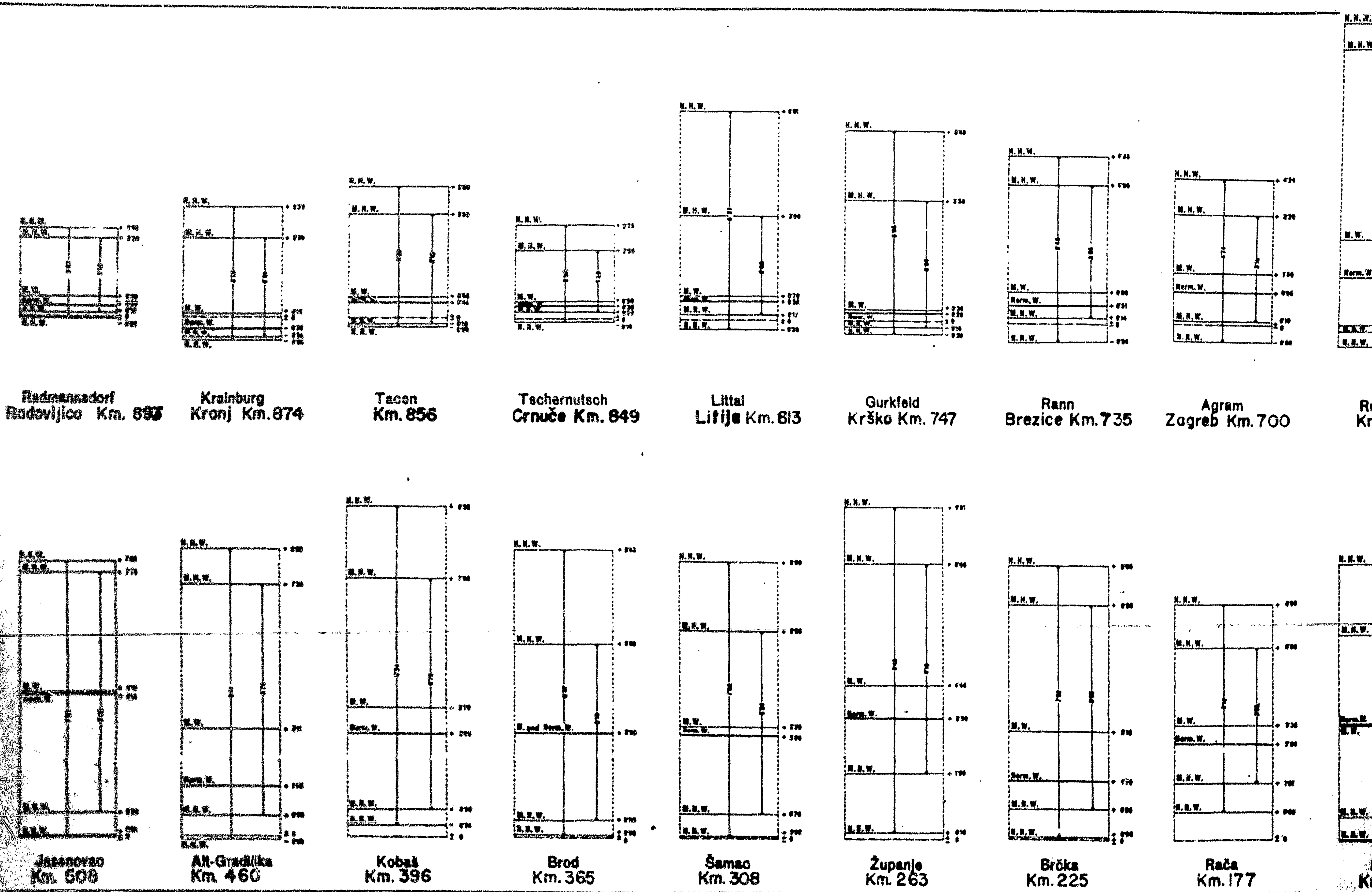
MILITARY HYDROLOGY R & D BRANCH

WASHINGTON DISTRICT CORPS OF ENGINEERS

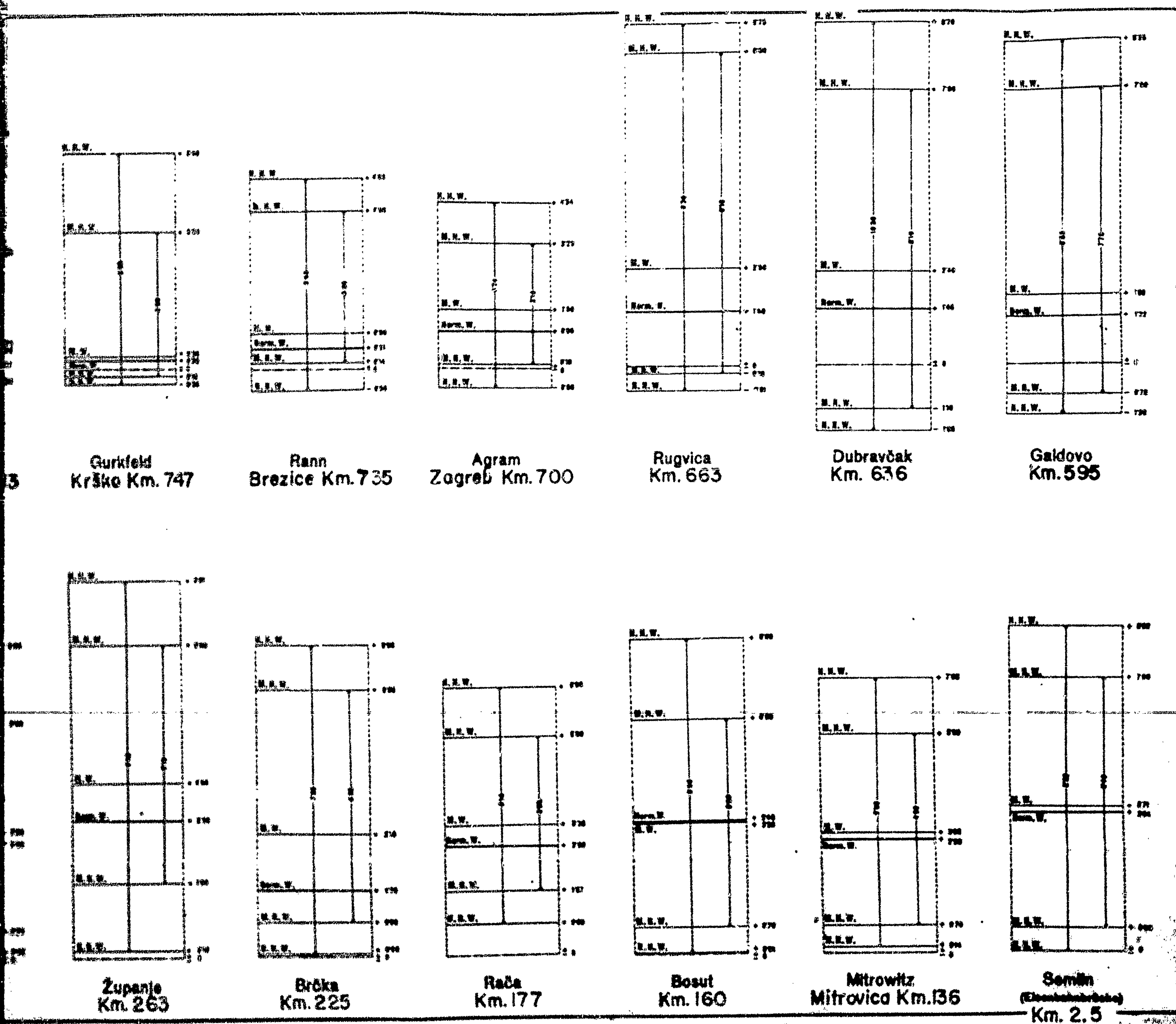
Prepared by *LJH* — Date *Feb 12, 1953*

Drawn by ______

PLATE 8



Radmannsdorf
Radovljica
Krainburg
Kranj Km. 874
Taoen
Km. 856
Tschernutsch
Crnuče Km. 849
Littai
Litije Km. 813
Gurkfeld
Krško Km. 747
Rann
Brezice Km. 735
Agram
Zagreb Km. 700
Jasenovac
Km. 508
Alt-Gradiška
Km. 460
Kobaš
Km. 396
Brod
Km. 365
Šamac
Km. 308
Županje
Km. 263
Bröka
Km. 225
Rača
Km. 177



NOTES:

1. Reproduced
bis zur Mün
Description
and its tri
Austrian Ar

2. Values show

3. Translation

a. The va
to fol

Radman
Agram-
Jasend

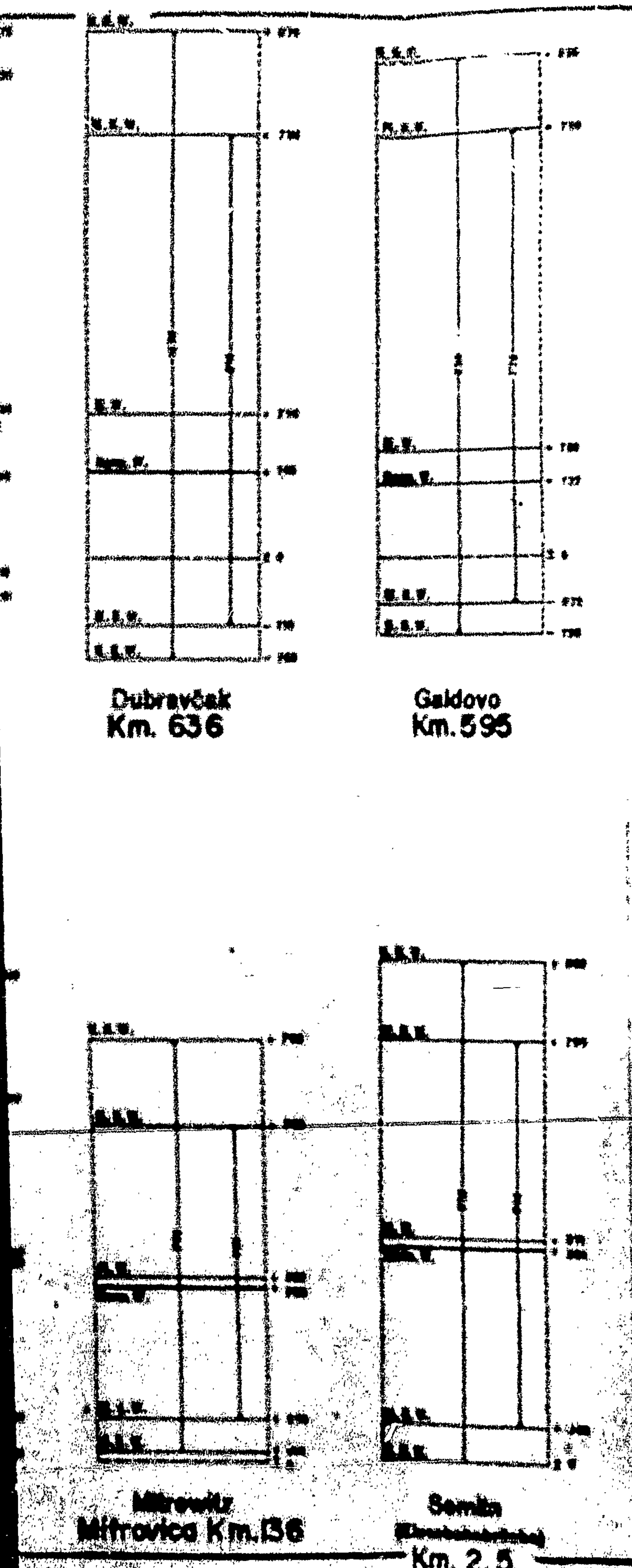
b. The H
enced

c. The g
right
dates
water

d. Abbre

H.H.
M.H.
M.W.
Norm
M.N.
N.N.

1 0 1 2



NOTES:

1. Reproduced from "Allgemeine Beschreibung der Save von Radmannsdorf bis zur Mündung und ihrer Nebenflüsse exklusive Drina" (General Description of the Sava River from Radmonsdorf to the junction, and its tributaries exclusive of the Drina River). An official Austrian Army Publication, Vienna 1904.

2. Values shown are for periods prior to 1904.

3. Translation of explanation on original graph.

   a. The values for M.H.W., M.W., Norm. W. and M.N.W., correspond to following observation periods:

Reach	Length of Record
Radmannsdorf-Rann	7 years
Agram-Galdovo	2 "
Jasenovac-Junction	5 "

   b. The H.H.W. and N.N.W. values represent the extremes experienced since the start of regular observations.

   c. The gages at Brčka and Rača were moved from the left to the right bank, and their gage zeros adjusted for the observation dates; therefore it would appear that the datum for those water stage fluctuations are not entirely reliable.

   d. Abbreviations:

H.H.W.	=	Highest High Water
M.H.W.	=	Mean " "
M.W.	=	Mean Water
Norm. W.	=	Normal Water
M.N.W.	=	Mean Low Water
N.N.W.	=	Lowest Low Water

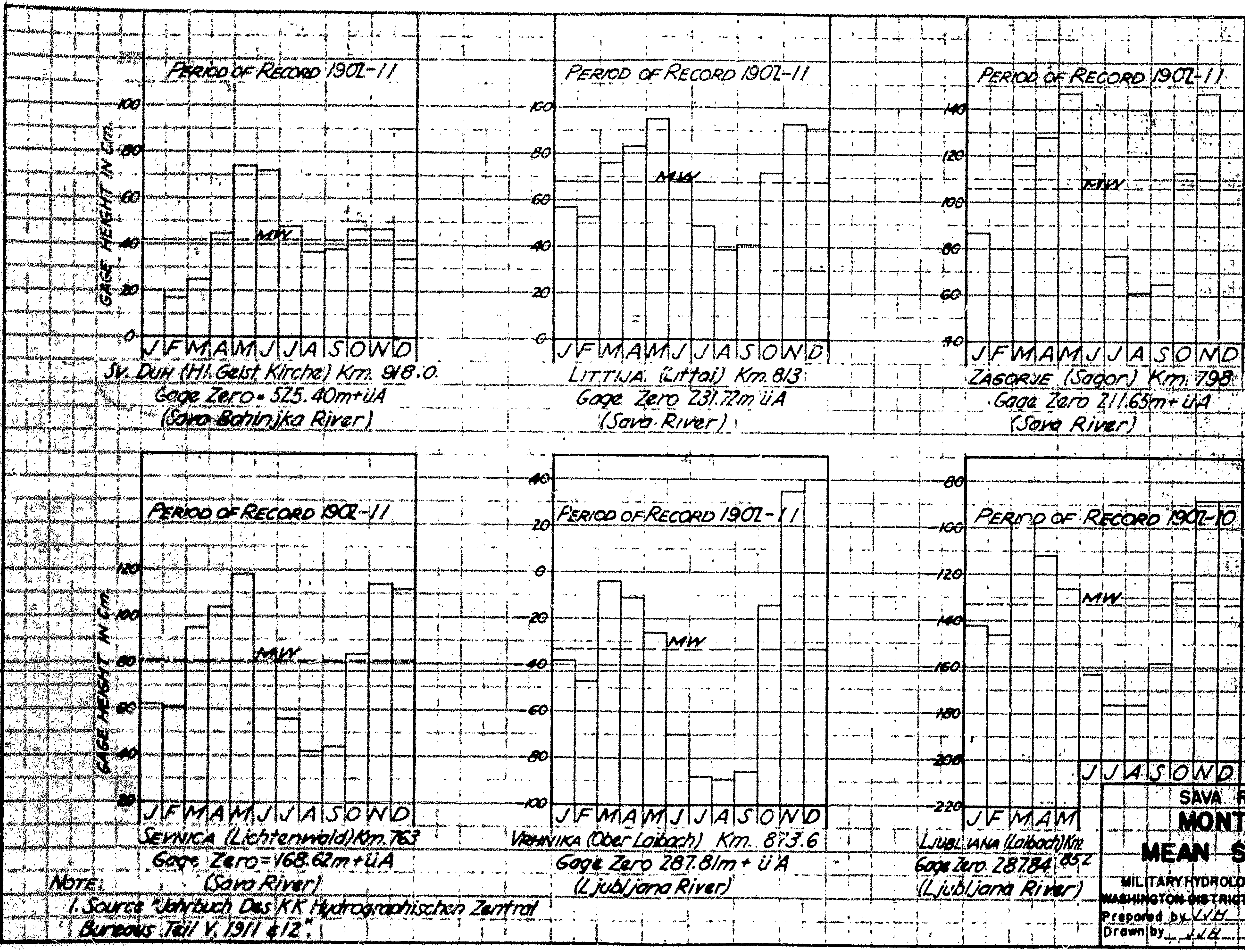
* SCALE*

1 : 0 1 2 3 4 5 6 7 8 9 10 m

SAVA RIVER
STAGE VARIATIONS

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JJH Date Feb. 12, 1953
Drawn by ______

PLATE 9

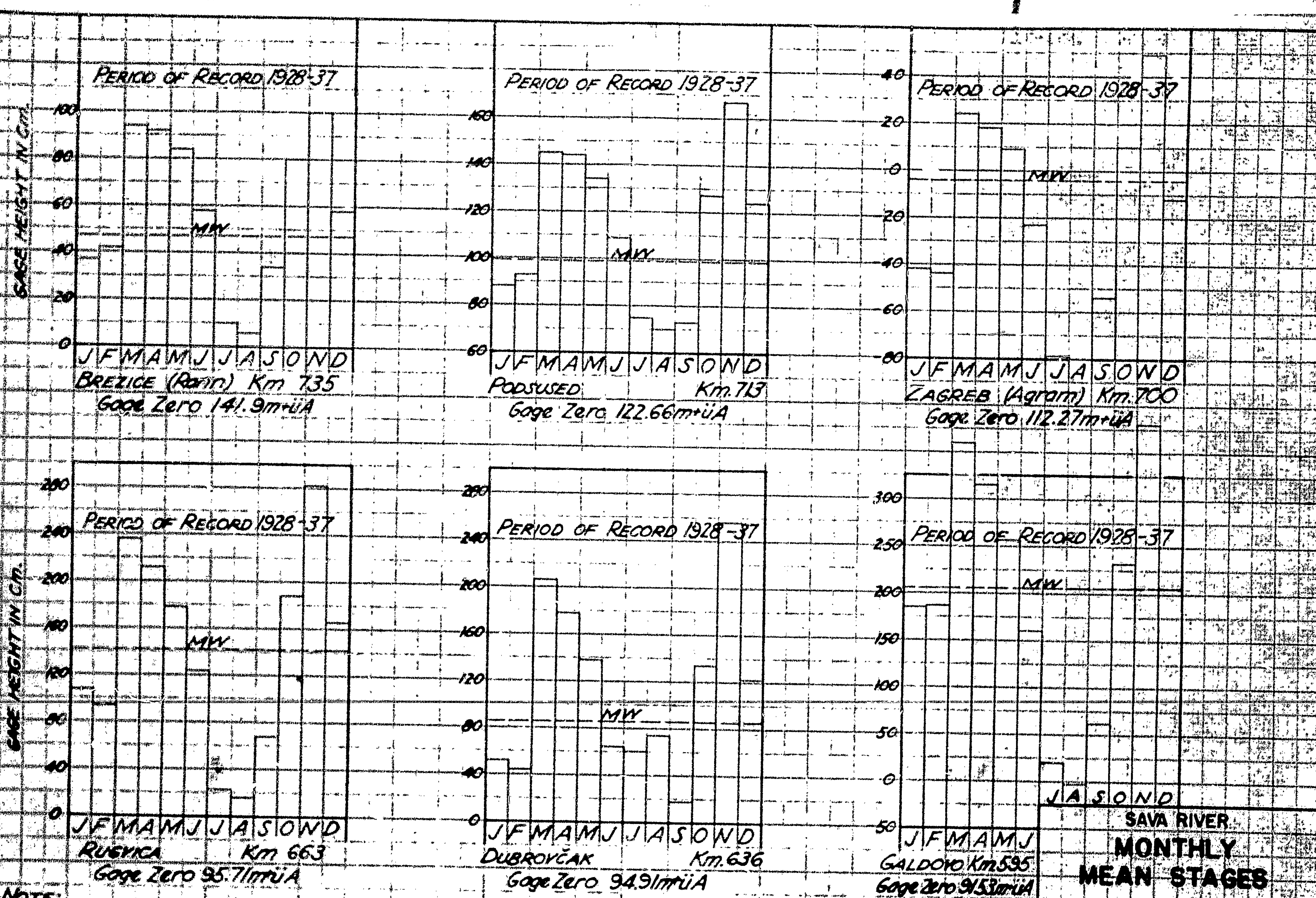


NOTE:
1. Source "Jahrbuch Des K.K. Hydrographischen Zentral Bureaus Teil V, 1911 & 12".

SAVA RIVER
MONTHLY MEAN STAGES

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JJH Date 8 May 1953
Drawn by JJH

PLATE 10



NOTE:

1. Source "Monografia Geografico-Militare sui Territori d' Occupazione della Croazia E Bosnia," p 49.

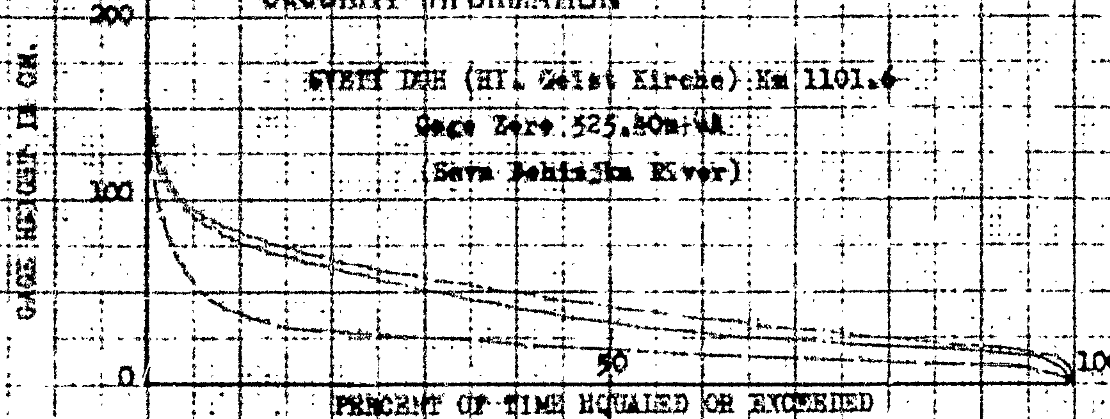
SAVA RIVER

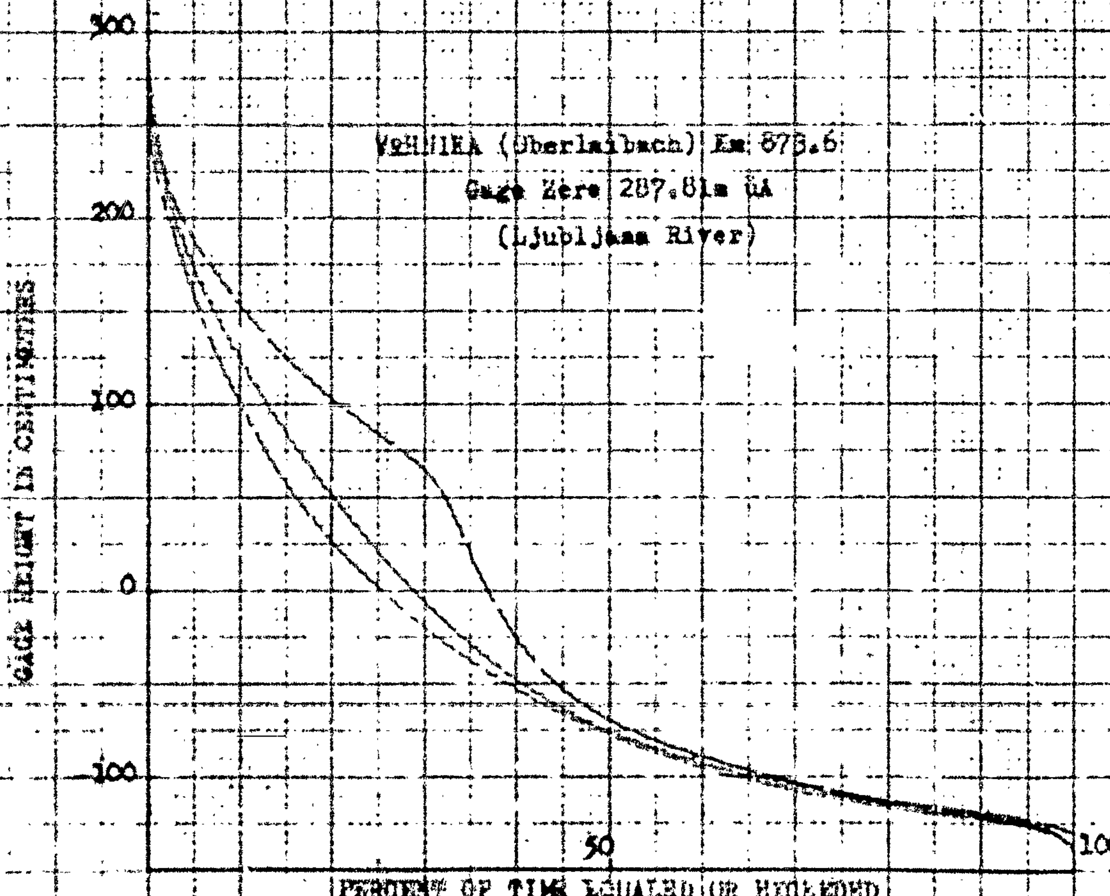
MONTHLY MEAN STAGES

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by J.J.A. Date 9 Mar 1953
Drawn by J.J.A.

PLATE 11

RESTRICTED
SECURITY INFORMATION





LEGEND

year (1 Dec.–30 Nov.)
winter (1 Dec.–28 Feb.)
summer (1 Mar.–30 Nov.)

NOTES
1. Source "Jahrbuch Des KK Hydrographischen Zentral Bureaus Teil V, 1911"
2. Period of Record 1907–1911

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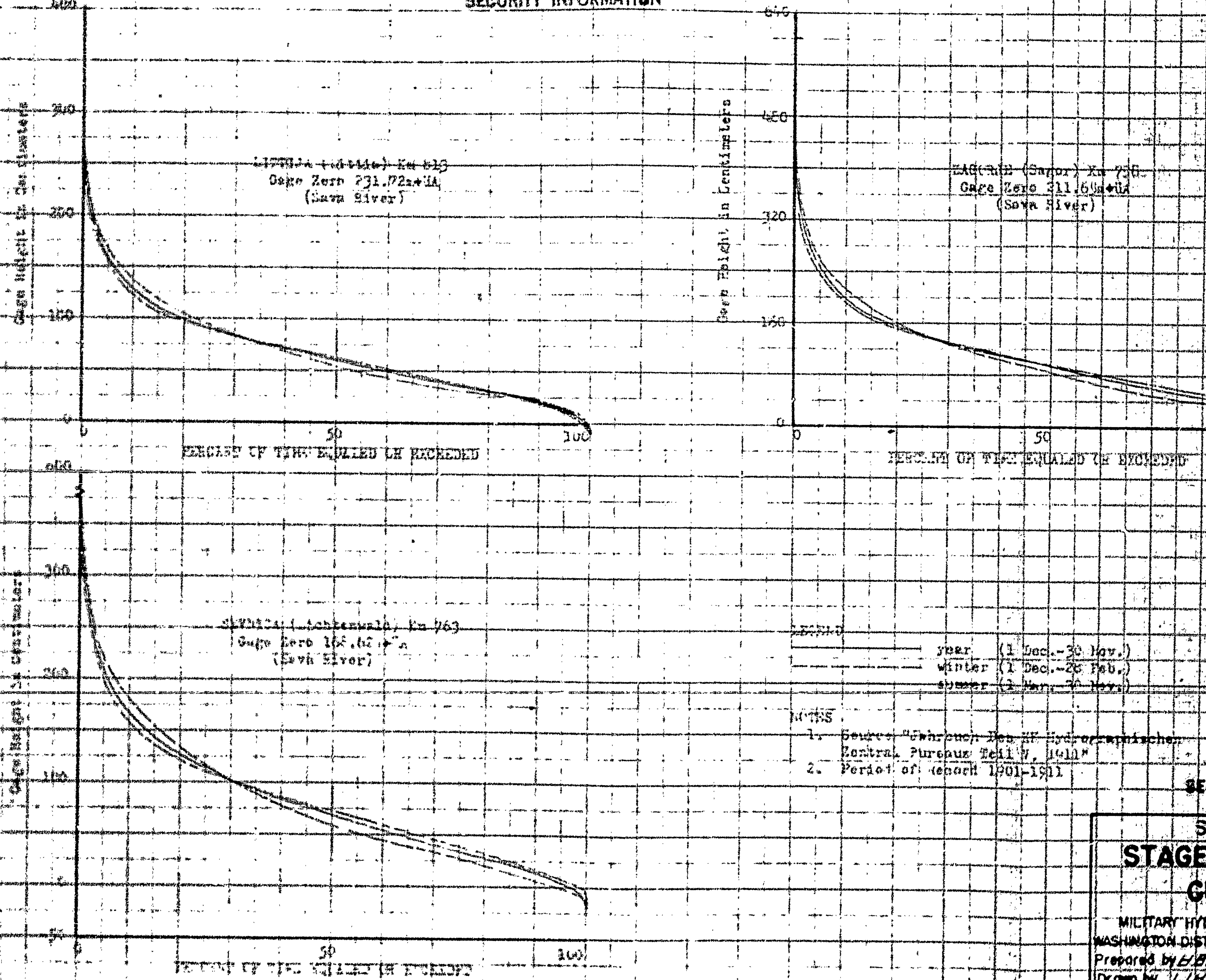
SECURITY INFORMATION

SAVA RIVER
STAGE DURATION CURVES

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by UB
Drawn by LH
Date 24 Feb. 1953



SAVA RIVER

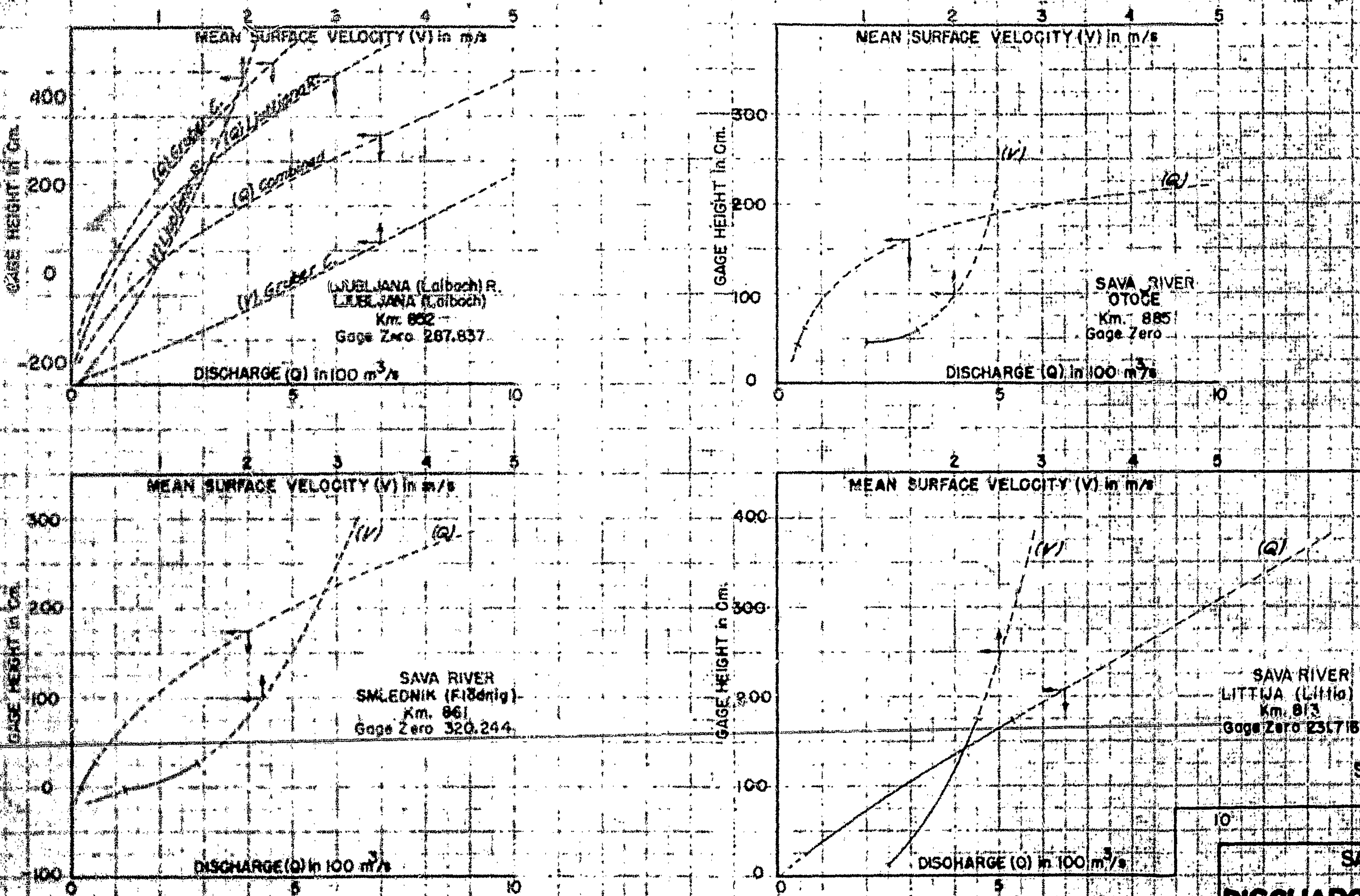
STAGE DURATION CURVES

MILITARY HYDROLOGY R AND D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by H.B. Date 10 Mar. 1953
Drawn by J.J.H.

PLATE 13

RESTRICTED
SECURITY INFORMATION



LEGEND (See Par. 3-05 & 3-06)
Limit of observed data
Estimated extension

RESTRICTED
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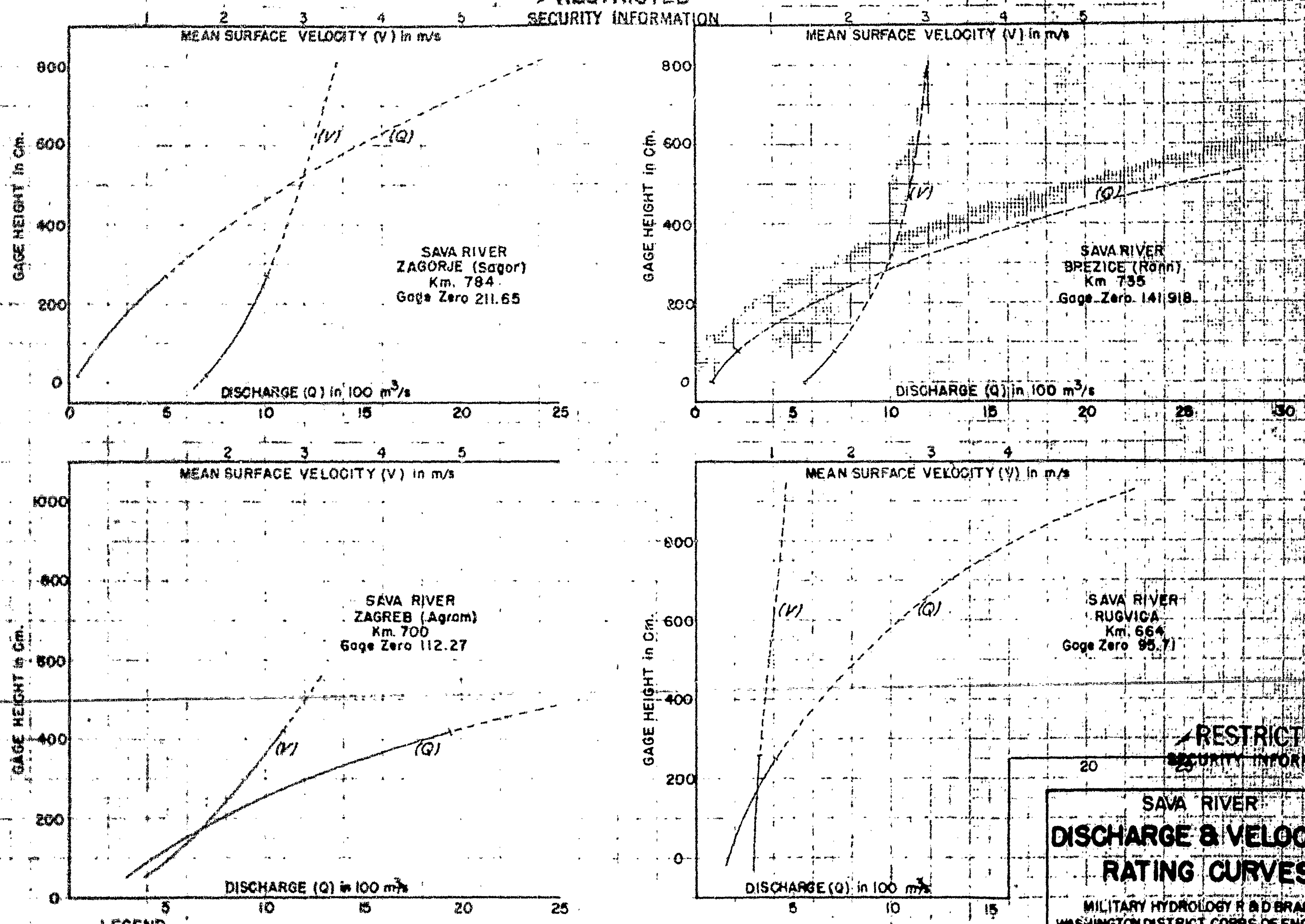
SAVA RIVER
DISCHARGE & VELOCITY RATING CURVES

MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by V.B. Date 3 Mar. 1953
Drawn by V.B.

PLATE 14

RESTRICTED
SECURITY INFORMATION



LEGEND
See Plate 14

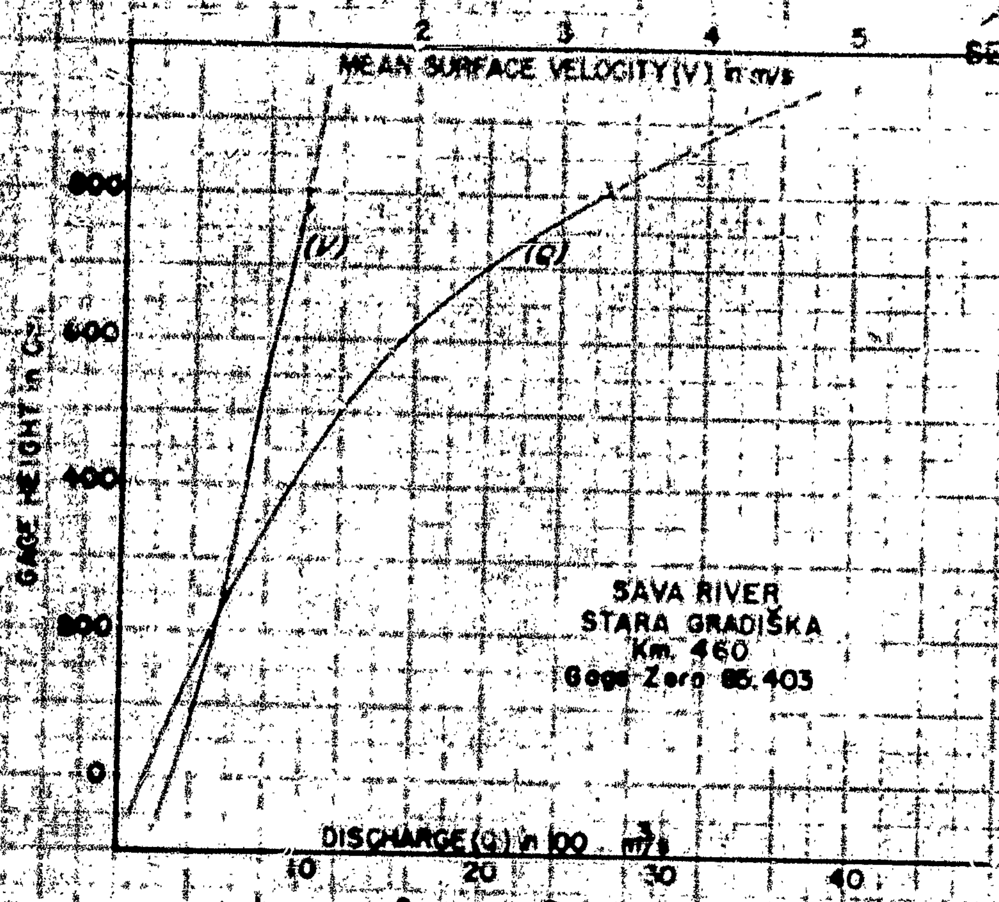
RESTRICTED
SECURITY INFORMATION

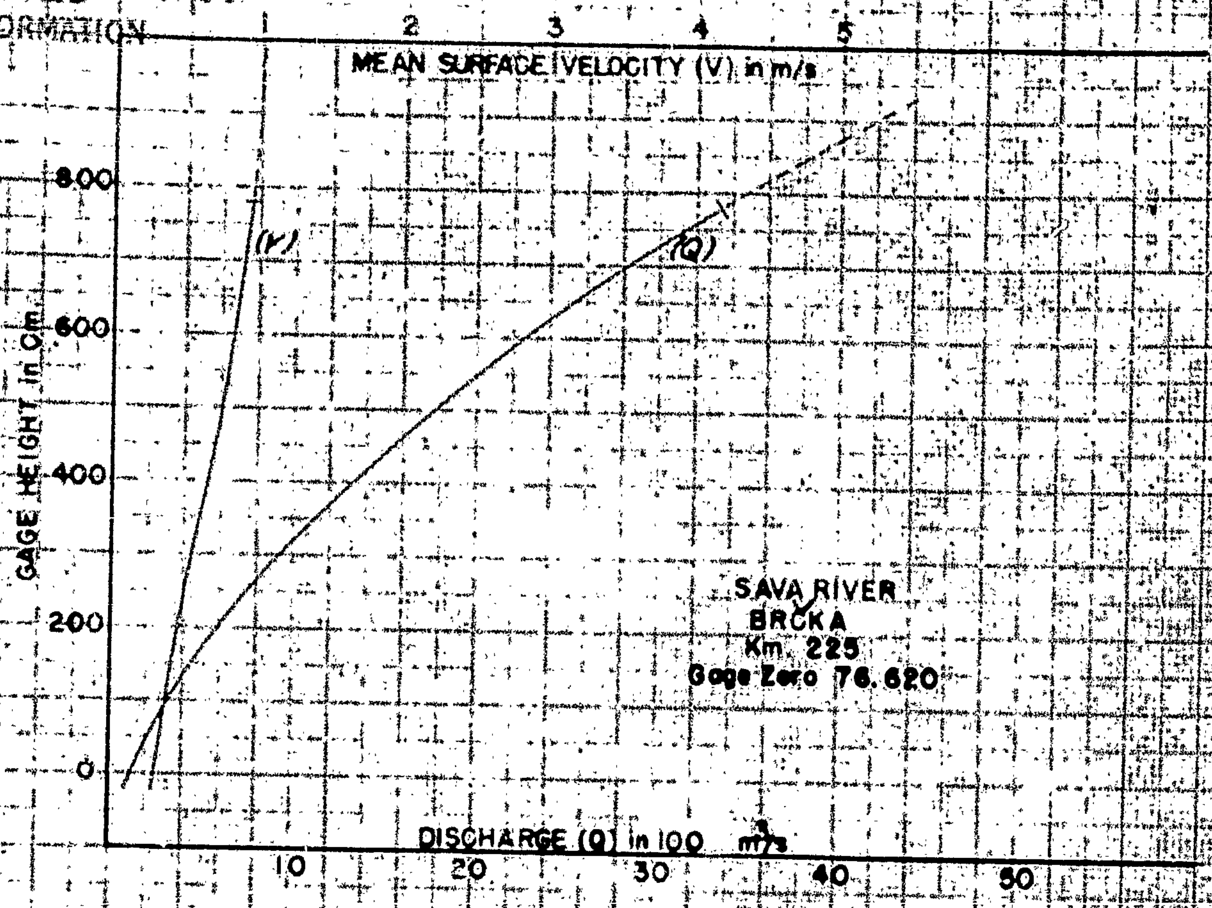
SAVA RIVER
DISCHARGE & VELOCITY RATING CURVES

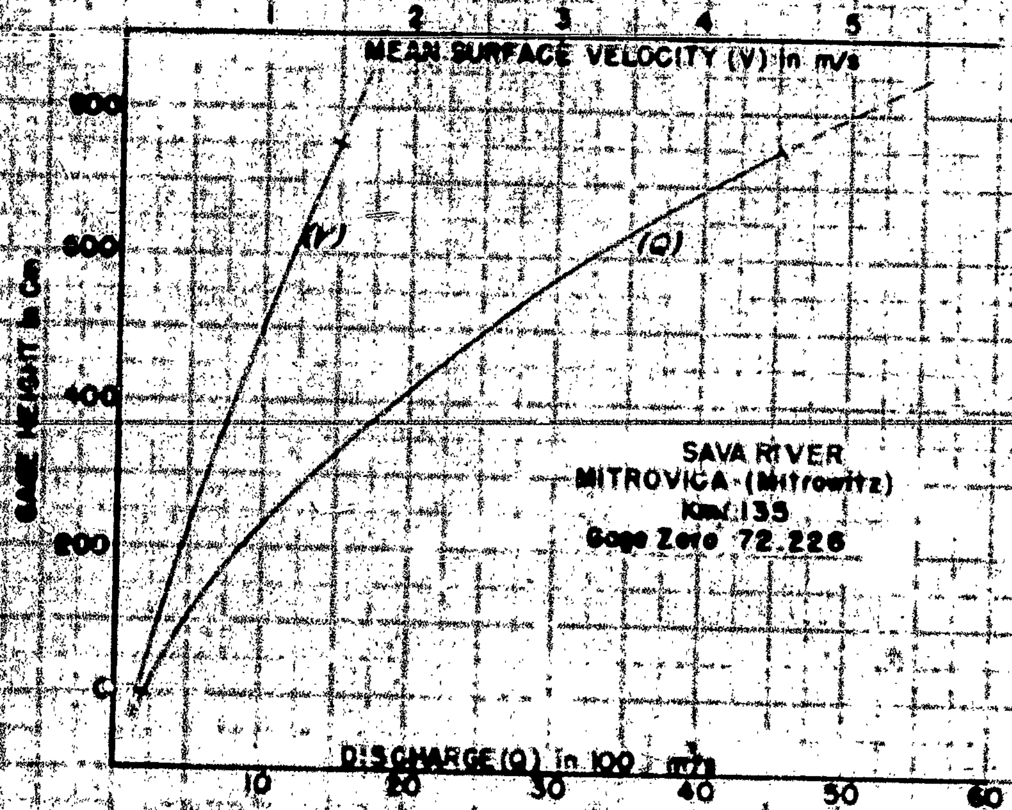
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by V.B. Date 4 Mar. 1953
Drawn by V.B.

PLATE 15

RESTRICTED
SECURITY INFORMATION







LEGEND
See Plate 14

RESTRICTED
SECURITY INFORMATION

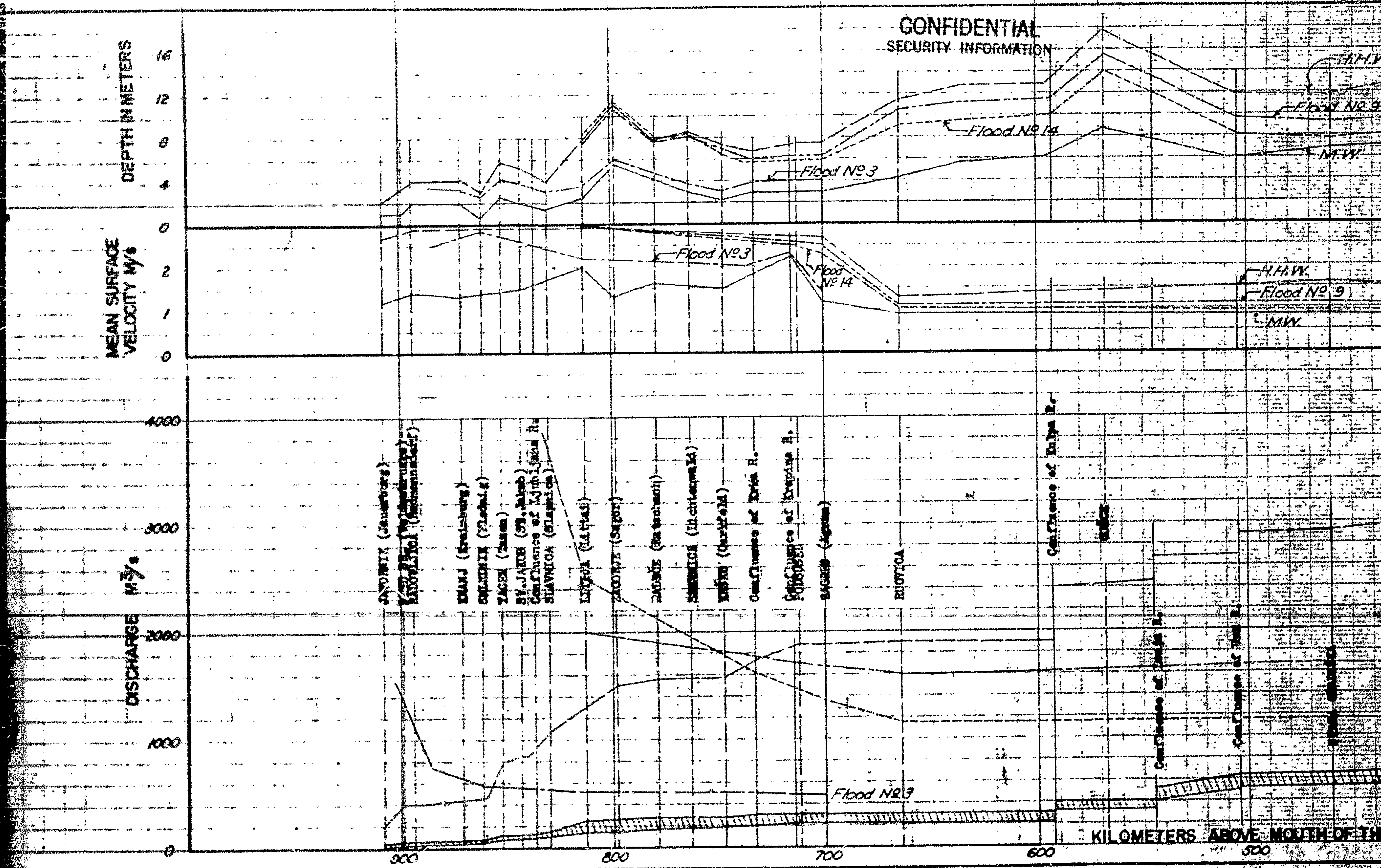
SAVA RIVER

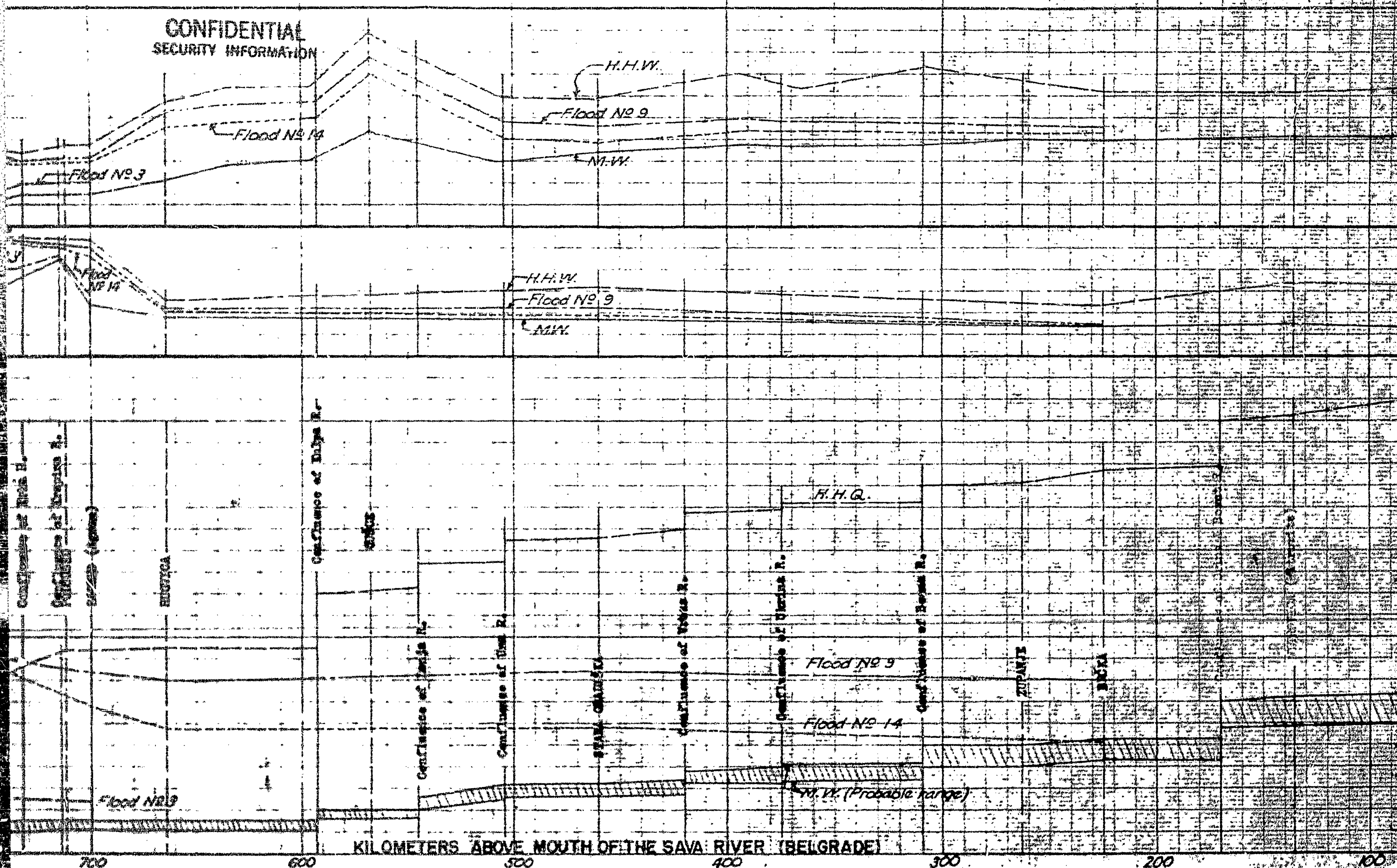
DISCHARGE & VELOCITY RATING CURVES

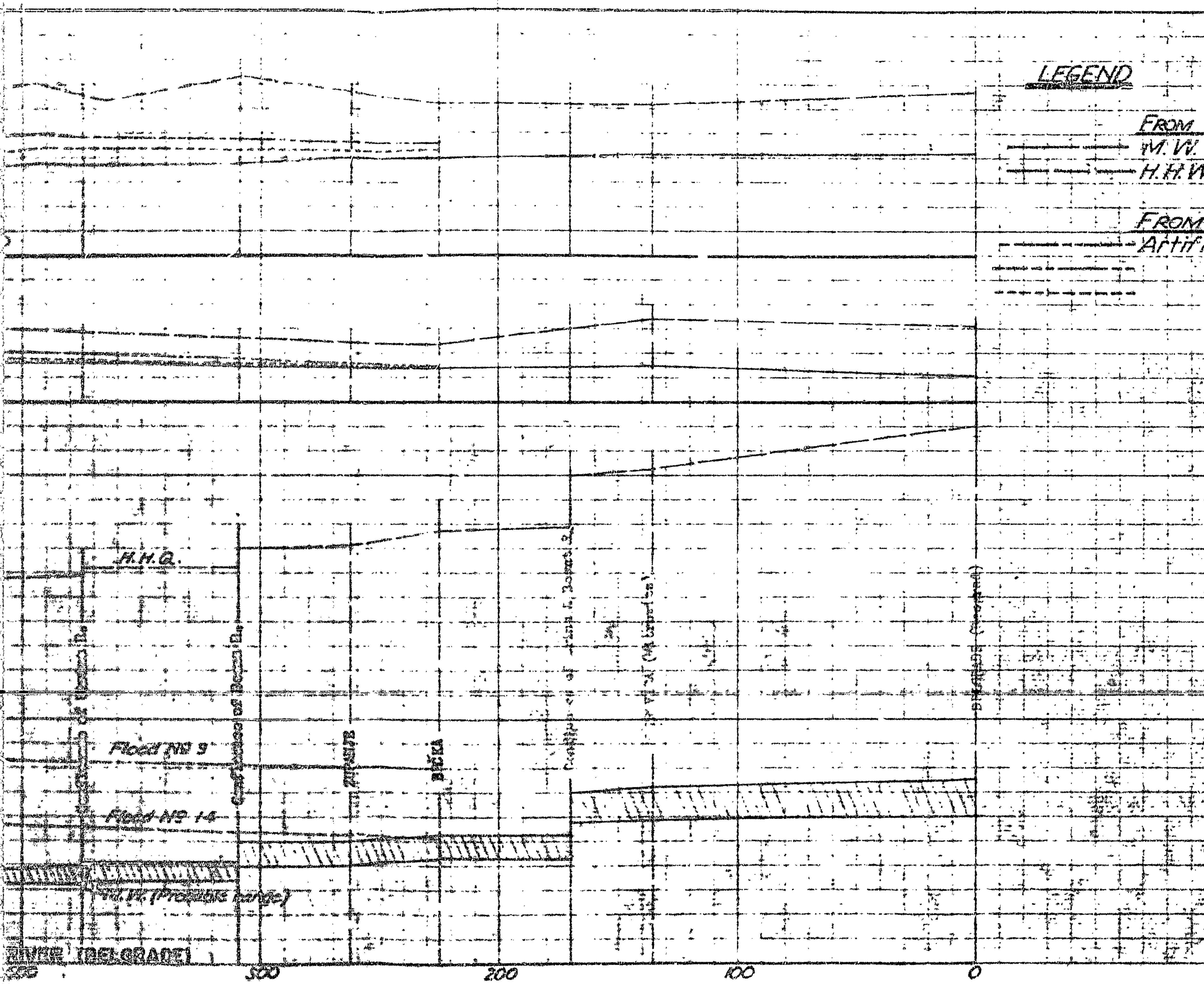
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by VB Date 4 Mar 1953
Drawn by VB

PLATE 16

CONFIDENTIAL
SECURITY INFORMATION




H.H.W.
Flood No 9
Flood No 14
M.W.
Flood No 3
H.H.Q.
M.W. (Probable range)
Flood No 19
Confluence of Drina R.
Confluence of Una R.
Confluence of Vrbas R.
Confluence of Bosna R.
STARA GRADIŠKA
ŽUPANJE
BRČKA
KILOMETERS ABOVE MOUTH OF THE SAVA RIVER (BELGRADE)
700
600
500
400
300
200
100

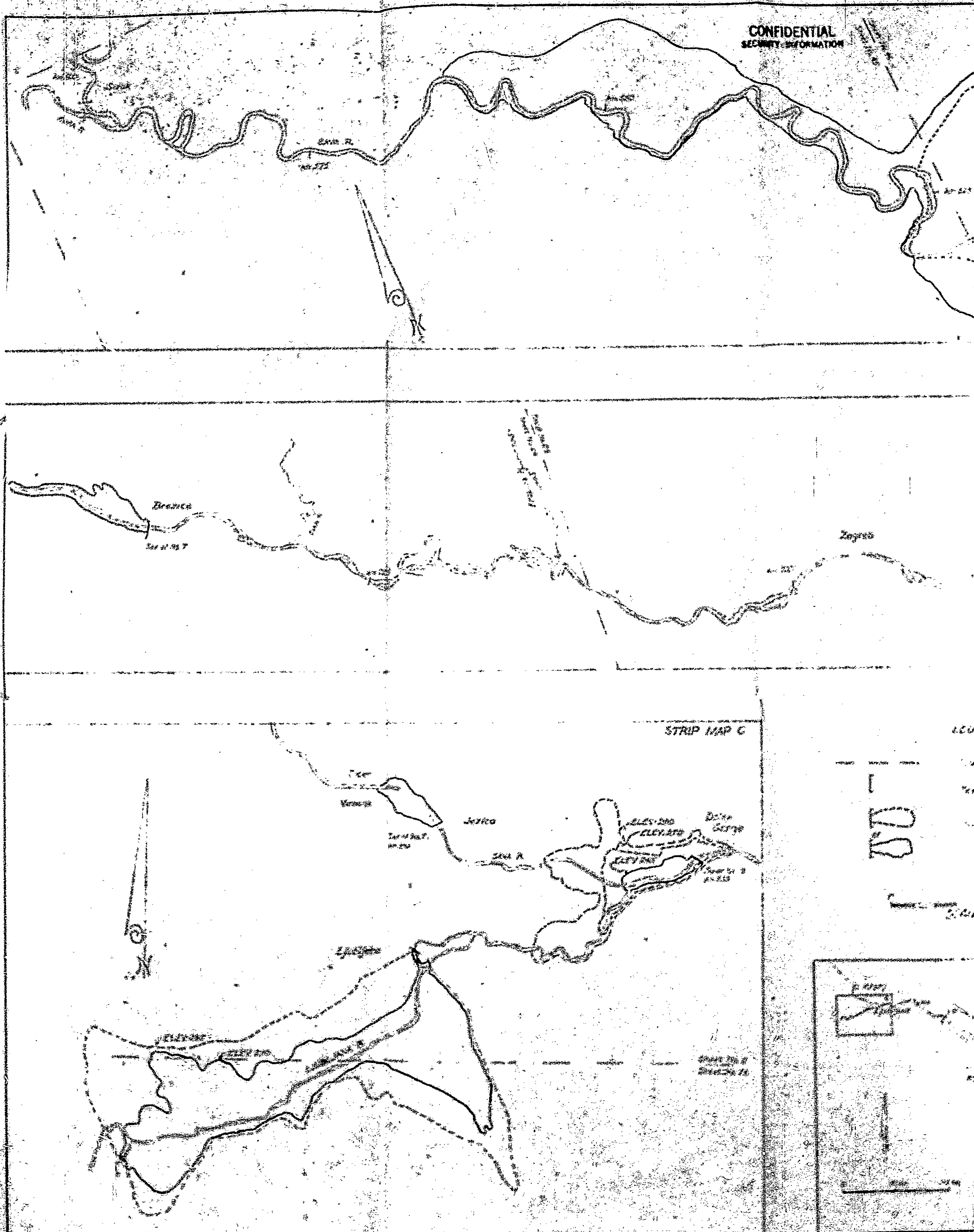


CONFIDENTIAL
SECURITY INFORMATION

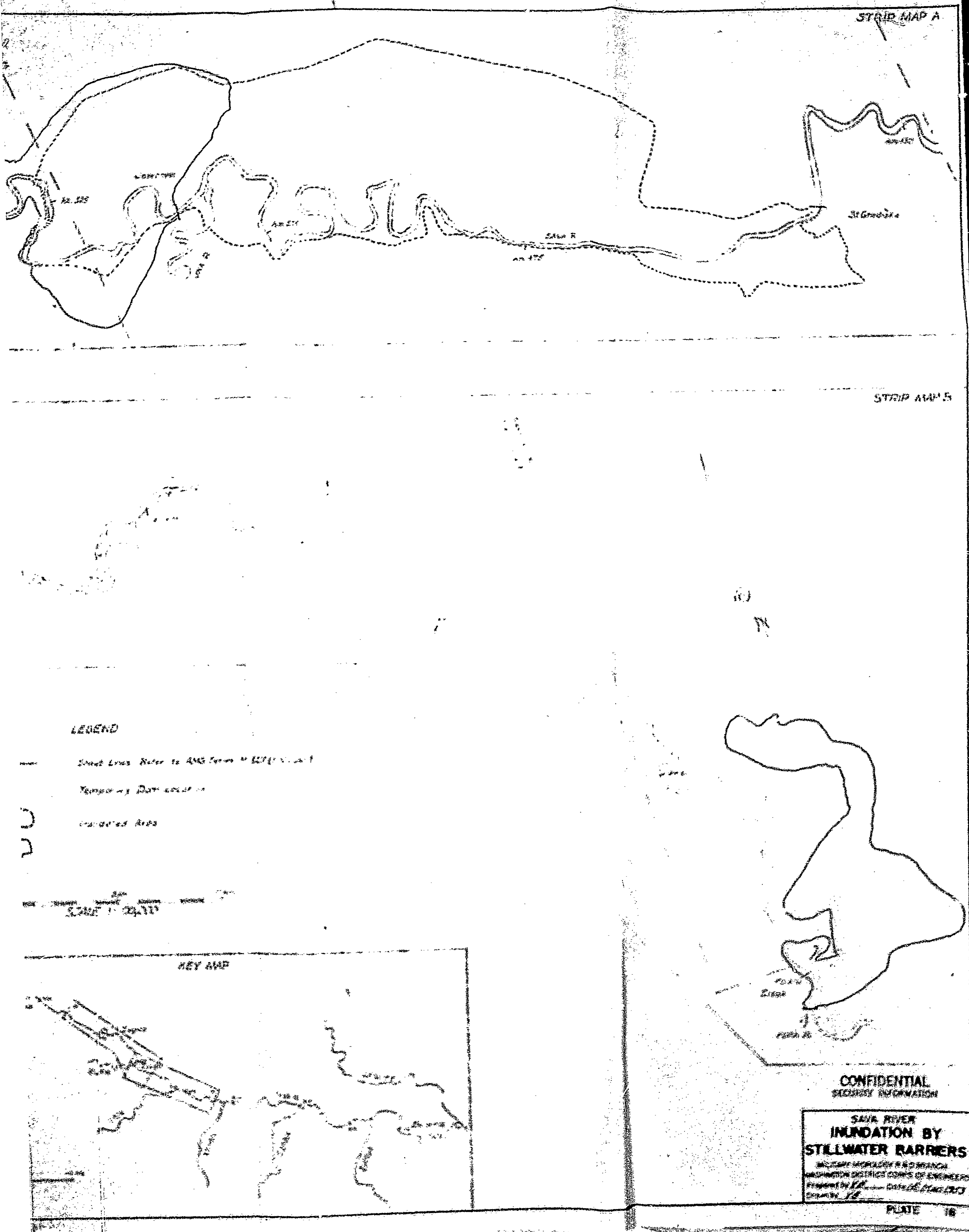
SAVA RIVER
DEPTH, DISCHARGE & VELOCITY PROFILE

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by V.B.
Drawn by J.J.H. Date [illegible]

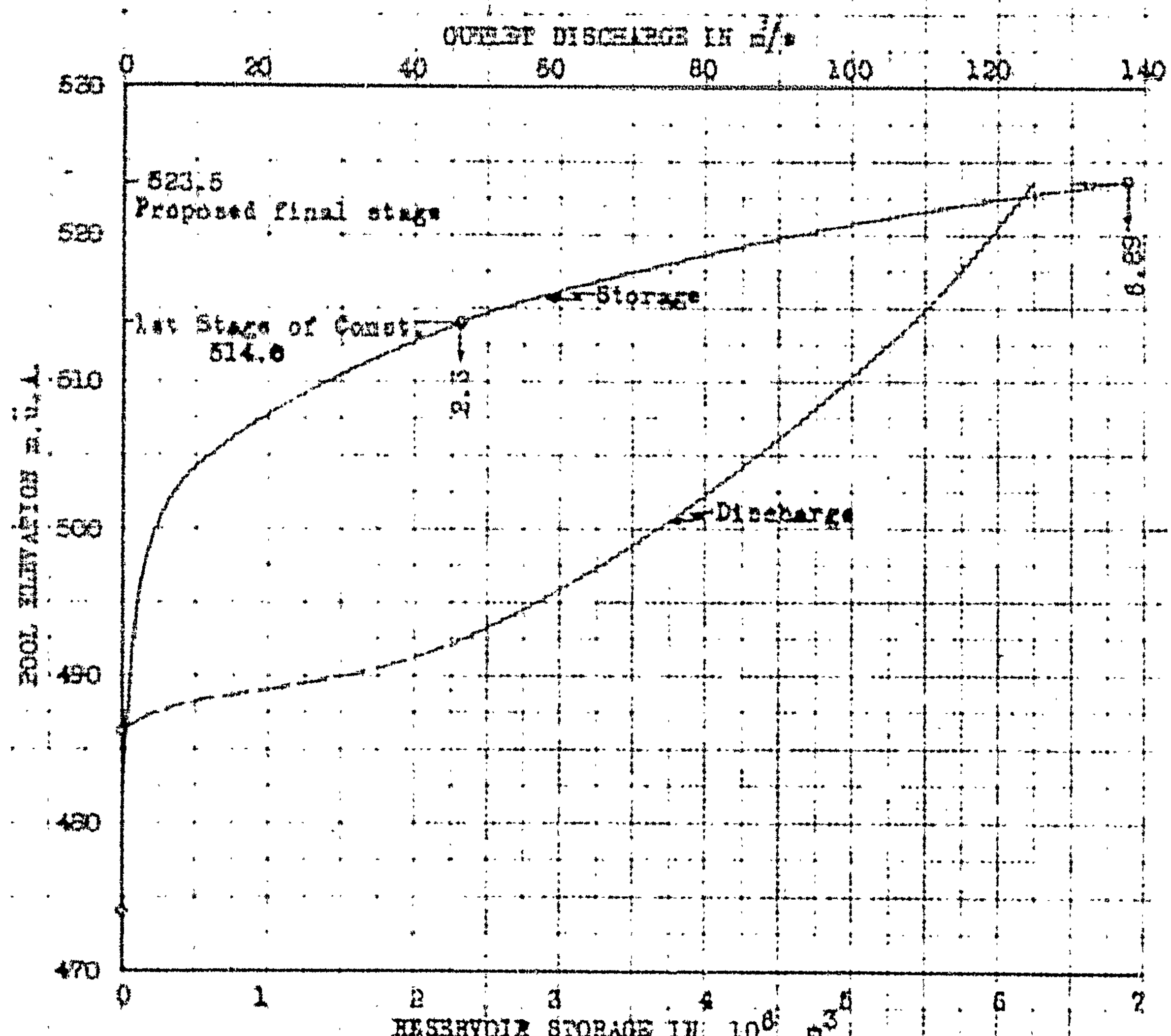
PLATE 17



CONFIDENTIAL
SECURITY INFORMATION
Brezice
Zagreb
STRIP MAP C


STRIP MAP A
LEGEND
KEY MAP
CONFIDENTIAL
SECURITY INFORMATION
SAVA RIVER
INUNDATION BY
STILLWATER BARRIERS
PLATE 16

RESTRICTED
SECURITY INFORMATION

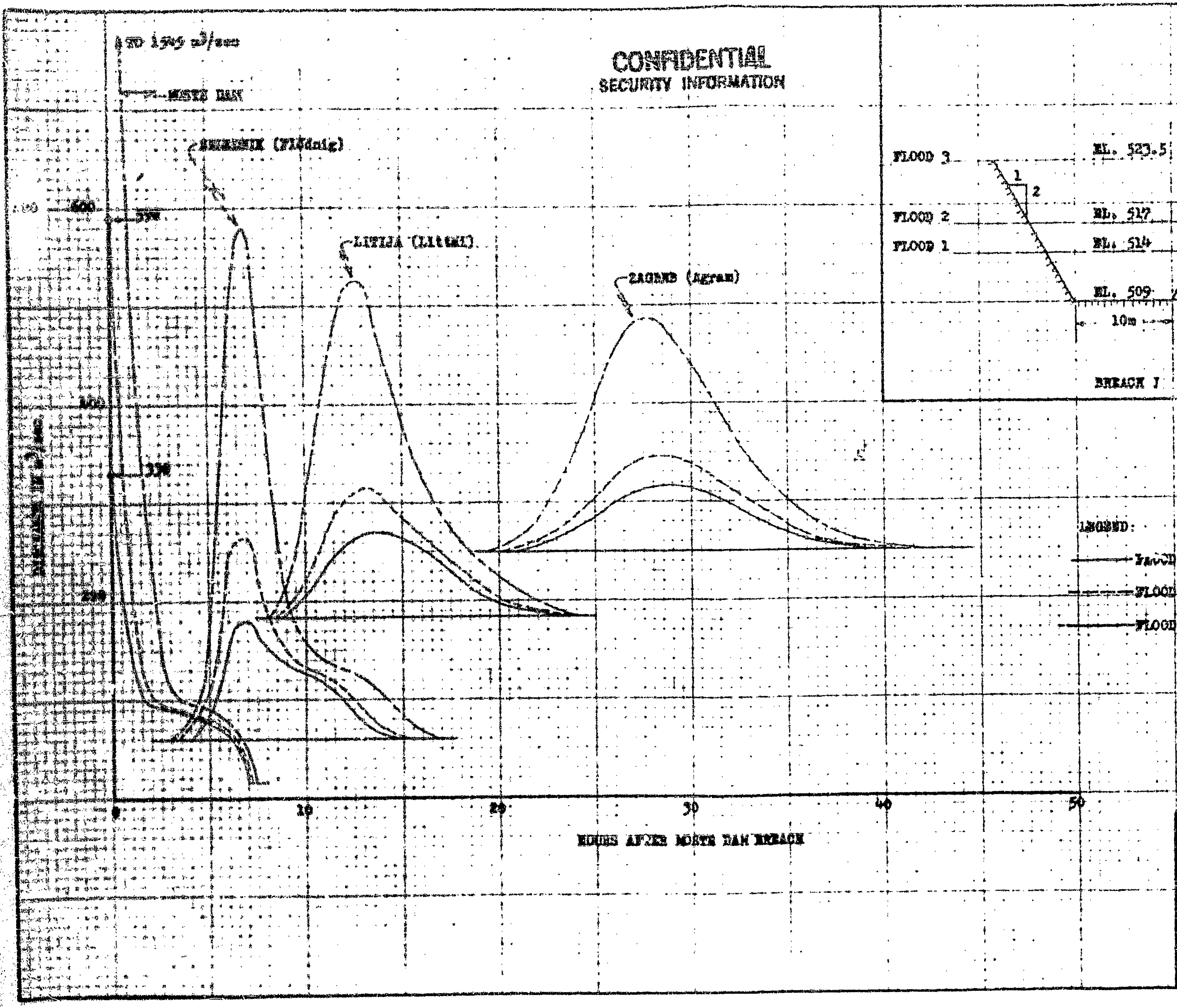


NOTE:
Curves estimated;
See Par. 4-03b and 4-04c

RESTRICTED
SECURITY INFORMATION

SAVA RIVER
MOSTE DAM
RESERVOIR STORAGE & OUTLET DISCHARGE
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT, CORPS OF ENGINEERS
Prepared by ___ Date 26 Mar. 1953
Drawn by ___

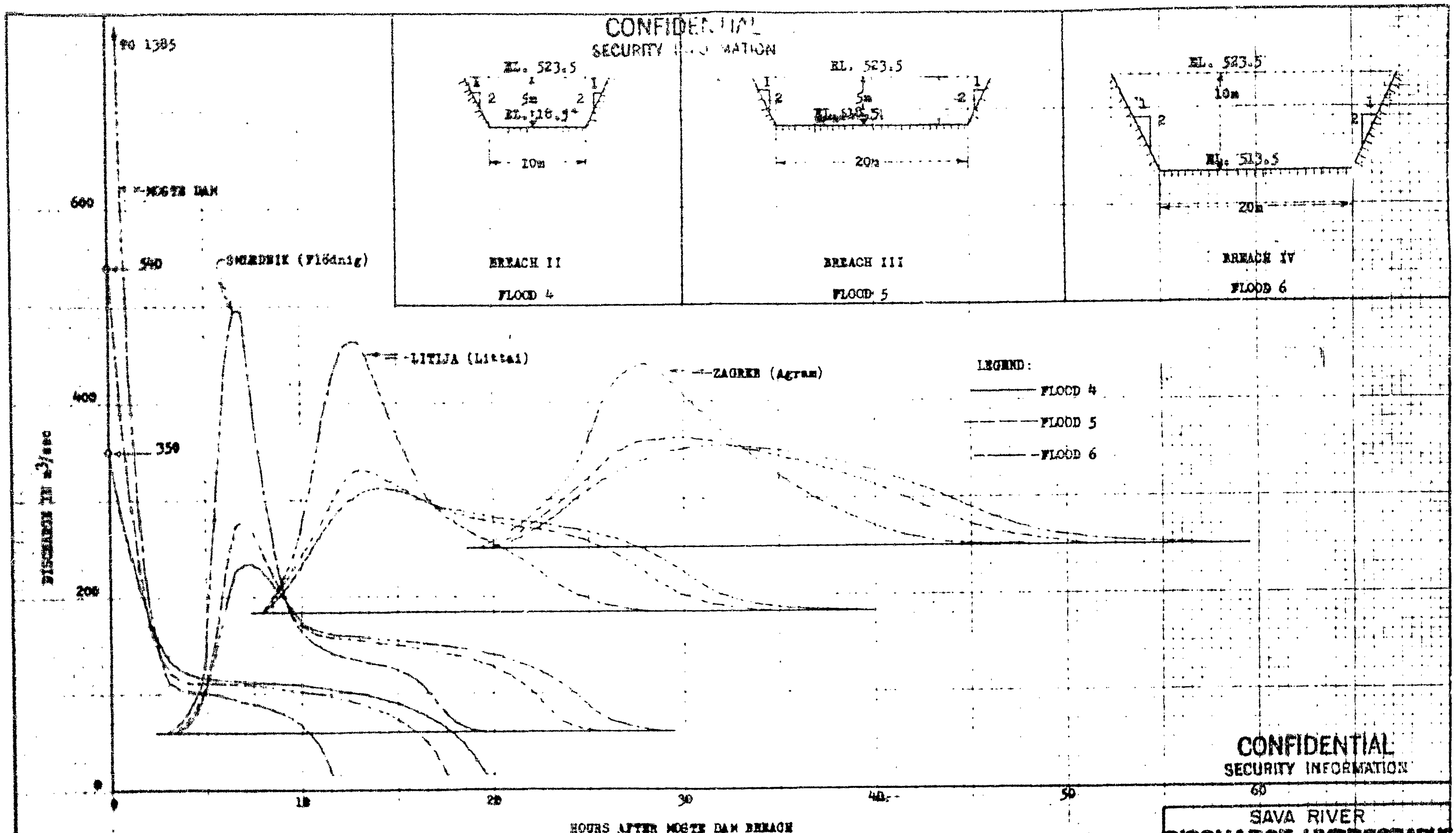
PLATE 19



CONFIDENTIAL
SECURITY INFORMATION

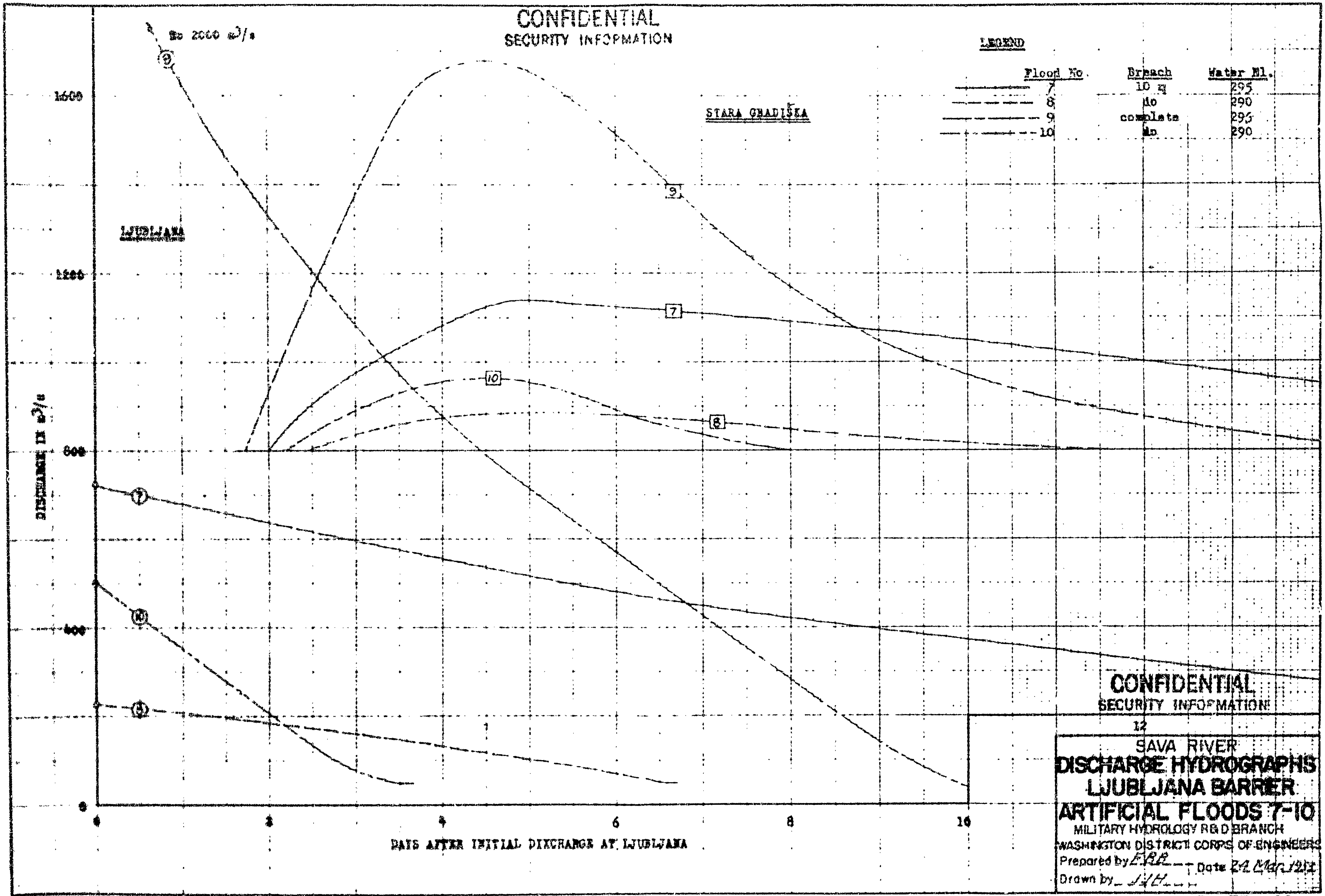
SAVA RIVER
DISCHARGE HYDROGRAPHS
MOSTE DAM
ARTIFICIAL FLOODS I-3
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by EBE Date 24 Mar 1953
Drawn by LLK

PLATE 20



SAVA RIVER
DISCHARGE HYDROGRAPHS MOSTE DAM ARTIFICIAL FLOODS 4-6
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by EBR Date 27 Mar 1953
Drawn by JJH

PLATE 21



CONFIDENTIAL
SECURITY INFORMATION

12

SAVA RIVER
DISCHARGE HYDROGRAPHS
LJUBLJANA BARRIER
ARTIFICIAL FLOODS 7-10
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by FRR Date 24 Mar 1952
Drawn by JJH

PLATE 22

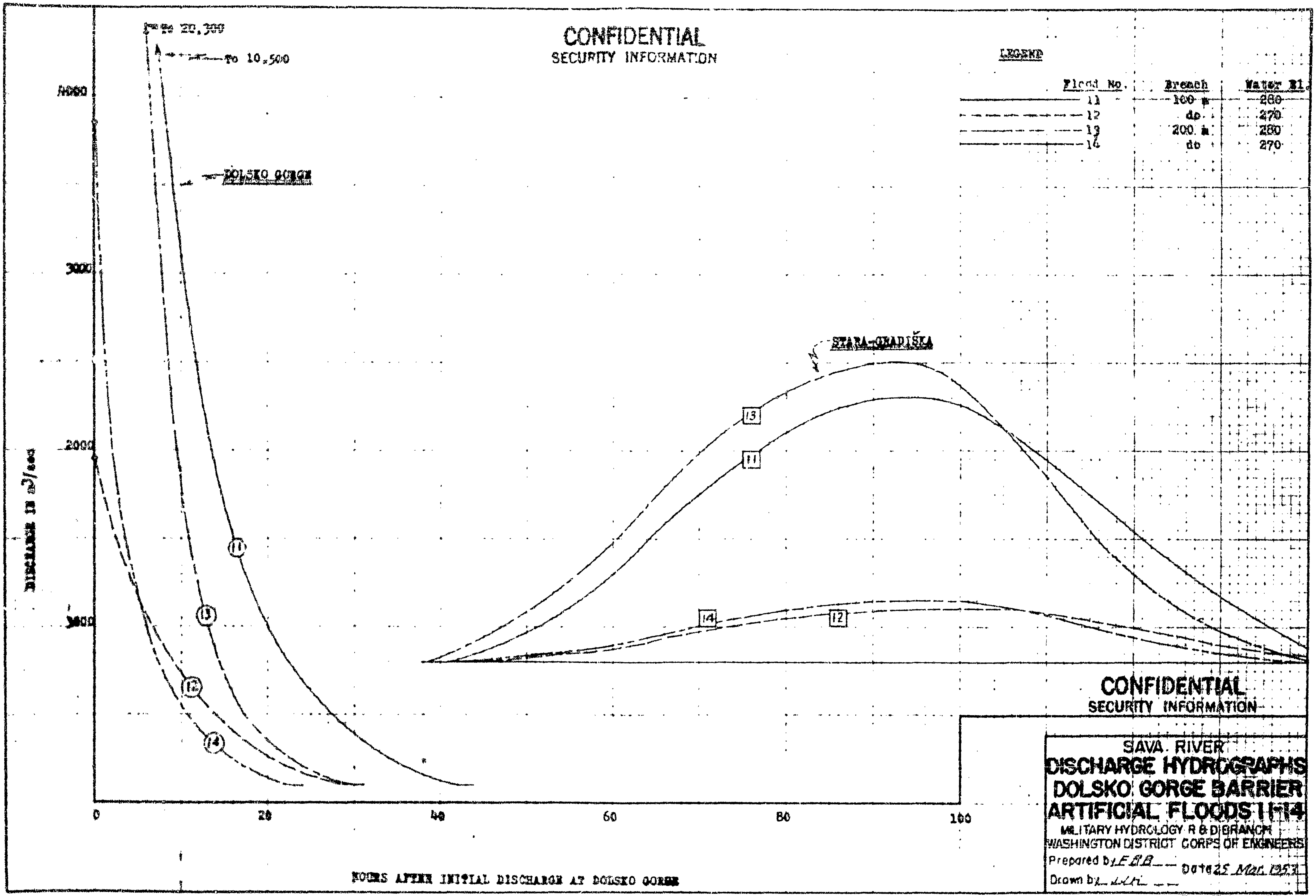

CONFIDENTIAL
SECURITY INFORMATION
LEGEND
Flood No. | Breach | Water El.
11 | 100 m | 280
12 | do | 270
13 | 200 m | 280
14 | do | 270
To 20,300
To 10,500
DOLSKO GORGE
STARA-GRADIŠKA
DISCHARGE IN m³/sec
4000
3000
2000
1000
0
20
40
60
80
100
HOURS AFTER INITIAL DISCHARGE AT DOLSKO GORGE
11
12
13
14
CONFIDENTIAL
SECURITY INFORMATION
SAVA RIVER
DISCHARGE HYDROGRAPHS
DOLSKO GORGE BARRIER
ARTIFICIAL FLOODS 11-14
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by E.B.B. Date 25 Mar. 1953
Drawn by

PLATE 23

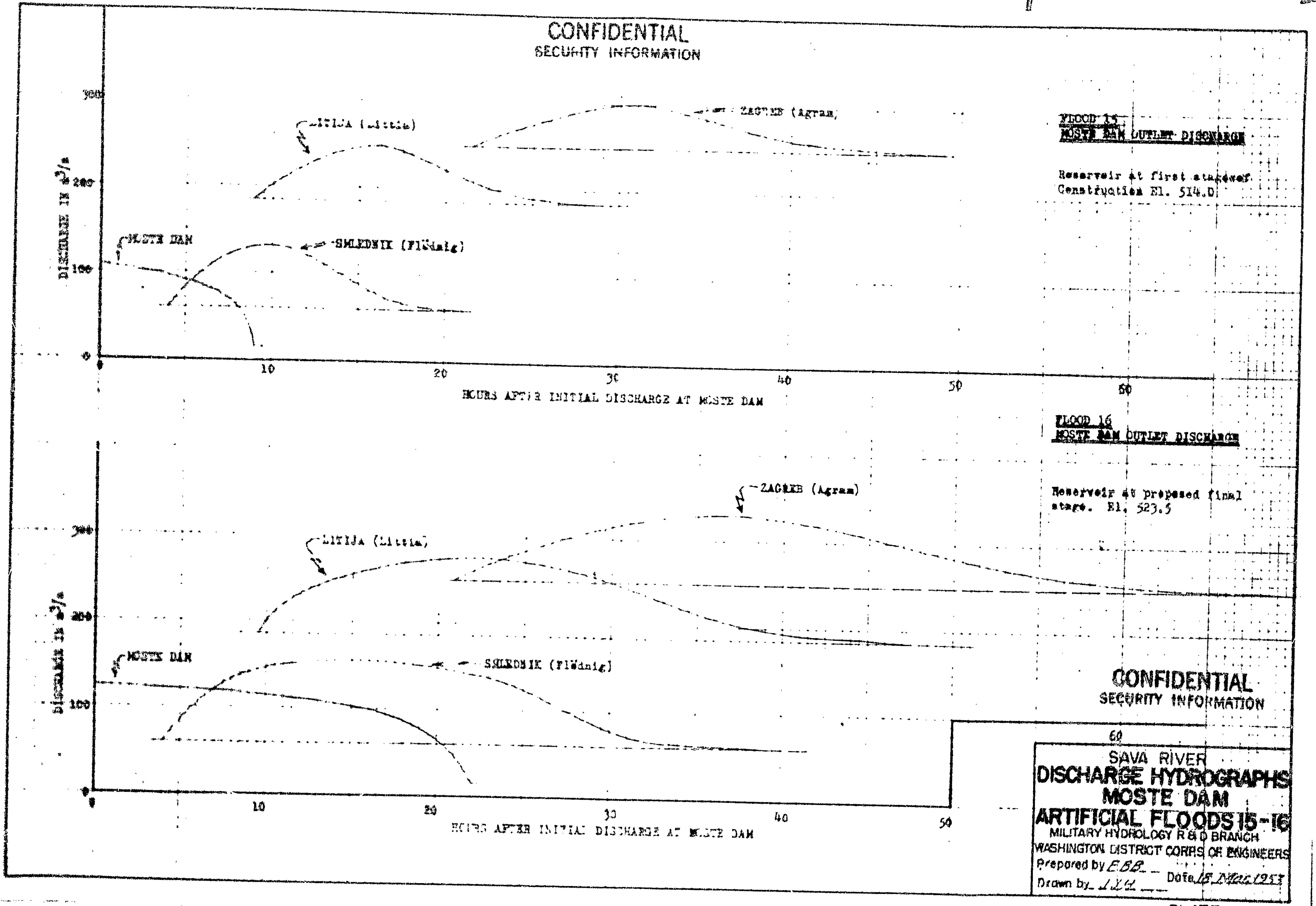

CONFIDENTIAL
SECURITY INFORMATION
FLOOD 15
MOSTE DAM OUTLET DISCHARGE
Reservoir at first stage of Construction El. 514.0
LITIJA (Littia)
ZAGREB (Agram)
SMLEDNIK (Flödnig)
MOSTE DAM
DISCHARGE IN m³/s
HOURS AFTER INITIAL DISCHARGE AT MOSTE DAM
FLOOD 16
MOSTE DAM OUTLET DISCHARGE
Reservoir at proposed final stage. El. 523.5
ZAGREB (Agram)
LITIJA (Littia)
MOSTE DAM
SMLEDNIK (Flödnig)
DISCHARGE IN m³/s
HOURS AFTER INITIAL DISCHARGE AT MOSTE DAM
CONFIDENTIAL
SECURITY INFORMATION
SAVA RIVER
DISCHARGE HYDROGRAPHS
MOSTE DAM
ARTIFICIAL FLOODS 15-16
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by E.B.B. Date 15 Mar. 1953
Drawn by J.K.H.

EXHIBIT A

ABSTRACTS OF TECHNICAL LITERATURE

ON THE SAVA RIVER

* References listed in the Bibliography of the report.

EXHIBIT A

ABSTRACTS OF TECHNICAL LITERATURE

ON THE SAVA RIVER

1. General Description of SAVA River
(Basis: Reference 7 *; "Yugoslavian Rivers," G-2, USFA)

a. Portion in SLOVENIA

(1) On account of the confining character of the KARAVANKA mountain chain, the valley of the upper SAVA forms the only natural entrance gate in the northwest corner of YUGOSLAVIA. The valley of the upper SAVA is confined on both sides by steep flanks; however, it has a wide bed of river gravel. The KARAVANKA mountain chain is joined in the east by the wide and high schistaceous mountains of POHORJE, with broad ridges and deep loam earth, which softens after rains. Further east is the plain of LJUBLJANA (LAIBACH). On the north side of this plain, we find the wild, rocky "SAVINJSKE ALPE" (STEINER ALPEN). In the northwest, outside of the narrow valley of the upper SAVA, the high alpine mountain chain of the TRIGLAV (TRIGLAV 2,865 m) group reaches far toward the south. In the west, we find the JULIAN ALPS, which have a dolomite character and deep valleys with abrupt slopes. From here on, the calcareous plateau with steep precipices continues to the plain of LJUBLJANA.

(2) The SAVA has its origin in the glaciers of the group of TRIGLAV, out of two alpine streams — SAVA-DOLINKA and SAVA-BOHINJKA, which comes from the BOHINJSKE JESERO (BOHINJSKE JESERO (BOHINJKA LAKE). These two streams join at RADOVLJICA. The waterfall of SAVICA is the continuation of the lakes of TRIGLAV. The large basin of LJUBLJANA is the exit of the SAVA out of the region of the ALPS. The northern part of the LJUBLJANA Basin, at approximately 400 m sea elevation is dry and is separated from the wet part in the south by the so-called "LJUBLJANSKI-BLATO" (LJUBLJANA MOOR) with its marshy, soft and swampy ground. The moor is, however, cultivated and used as meadows and pastures. The SAVA flows through the northernpart of the plain and leaves it through a very narrow gorge towards the east. This gorge between LITIJA and SEVNICA (deep and narrow, approximately 800 m) belongs to a steep calcareous chain of mountains called "SAVABERGLAND." In this reach, the SAVINJA flowing from the north joins the ZIDANI MOST. It makes a sharp turn toward the south, breaking through the calcareous chain of the SAVABERGLAND. Southeast from the SAVINJA region, the SAVA flows in SAVABERGLAND to the boundary of CROATIA. The land is flat and rolling with isolated, wild mountain ranges. The wide plains are still lacking here as well as in the SAVINJA region, despite the open land and individual basin flats.

(3) The climate of SLOVENIA is wet in the highlands and proportionately dry in the basins. The mean annual precipitation varies from 700 to 2,500 mm. October is considered as the month of highest precipitation. The winter is cold with abundant snowfalls; the summer is slightly warmer than in AUSTRIA.

* Reference listed in the Bibliography of the report.

b. Portion in CROATIA, SLAVONIA and MACVA

(1) CROATIA and SLAVONIA are characterized by wide and deep stream flats. The stream plains of the SAVA, after its exit from the narrow valley above ZAGREB, has the character of a wide basin. Between ZAGREB and the mouth of the VRBAS River the SAVA depression reaches its largest width. It is composed of rubble fields covered by loam, consisting of humous earth, beginning at SISAK, and gradually changing into black earth towards the east. Southeast of ZAGREB, the depression is further widened by the plain of KARLOVAC. This plain has many swampy parts. In the east, on the north side of the valley of SAVA, we find a mountainous area called the POZEGA Mountains. In the middle of these mountains is located the large and rich basin of POZEGA. The wide mountain chain of POZEGA once more confines the wide flat land. The SAVA, which is in this part is already a very large stream, then enters the DANUBE DEPRESSION. This flat region is called "SREM" and has exactly the same character as the wide plains of SOUTH HUNGARY. The "MACVA" between the low reaches of the DRINA and SAVA Rivers corresponds in characteristics to the flat plain of "SREM." In early summer and autumn, much of this region is flooded and, consequently, the ground is very soft. The stripe of land along the SAVA River are also subject to inundations. The climate of CROATIA, SLAVONIA and MACVA has a distinctive continental character with very warm summers and severe winters with little snow.

(2) The SAVA River is navigable between SISAK (km 590) to its junction with the DANUBE at BELGRADE (km 0). At the beginning of World War II, the YUGOSLAV Government undertook extensive regulation developments on the SAVA River, in order to extend the navigation from SISAK up to ZAGREB. High water appears usually in March and April (also in October and November). The July-September period is a low water season. Navigation is usually interrupted for 60 to 70 days per year, due to ice and to low water conditions. During the last 60 years, numerous protective levees have been built along the SAVA. Usually only local conditions have been taken into account in the planning of these protective hydraulic structures. However, no overall flood protection planning was done. Consequently, many of these protective levees on the lower SAVA are exposed to danger of overtopping and collapse during high flooding conditions. These conditions have resulted in the creation of numerous ponds (often at a great distance from the river), which require permanent drainage.* These drainage works are being performed at present on the "LONJSKO, ODRANSKO and TREBISKO POLJE" and in the "BOSANSKA POSAVINA" (report of the periodical "Tehnika No. 4 of 1949").

2. Hydrologic Features of the Sava River
(Basis: Reference 5: "Jugoslavia," BR. 493
Reference 11: "Jugoslovija-Zemljopisni," Melik
Reference 12: "Italo-Yugoslav Boundary," Moodie
Reference 13: "Polaci, sa Regulaciju Savo," Pisačić)

a. Drainage Areas. The SAVA River has a drainage area of 95,000 km^2, the largest watershed of any river in Yugoslavia. (Reference 11

* Translators Note; Original reads "Irrigations," but should logically be "drainage."

gives 95,107 km^2 and Reference 13 gives 94,696 km^2*. It drains 37.1 percent of the entire YUGOSLAV territory. The total length is 1,060 km (according to Reference 13). It is navigable between SISAK and BEOGRAD, a distance of 600 km.

b. Discharge. Reference 11 gives, for the discharge of the SAVA River at junction with the DANUBE River at BEOGRAD, a maximum of 4,078 m^3/sec, a minimum of 608 m^3/sec, and a mean of 1,120 m^3/sec, which corresponds to 35.3 km^3 mean yearly volume of discharge. Based on more recent information, reference 11 cites 48.2 km^3 as the mean yearly discharge volume, corresponding to 1,520 m^3/sec.

c. Underground Flow.

(1) The outstanding characteristics of YUGOSLAVIA'S hydrologic conditions are its underground runoff, rivers, and flows. About 9.5 percent of YUGOSLAV territory consists of so-called "Karst or Kras" (Italian name is "Carso"), a geological phenomenon marked by sinkholes, interspersed with abrupt ridges, protruding rocks, deep caverns, and drained by underground runoff, streams and rivers. Of this underground runoff, 2.6 percent flows towards the SAVA River basin.

(2) Being composed predominantly of limestone of varied age, (Jurassic and Triassic) the surface of the "Karst" is readily dissolved by rainwater and surface drainage. This gradually erodes any weak spot into an opening into which the water then sinks to flow underground. This underground inflow into the SAVA region is particularly noticeable on the LJUBLJANA River, a tributary of the SAVA River.

(3) The LJUBLJANA River system receives, in addition to its regular surface water, an appreciable supply of underground water from underground rivers and streams. The northward flow of these underground streams have been traced about 40 km from their origin in the NOTRANSKO region in the JULIAN KARST area. The underground rivers appear on the surface where they cross the so-called "polja." Those of PLANINA and CIRKVENICA are the two most outstanding. (Plate 3 of this report shows the underground drainage pattern of this region).

(4) "Polje" is a basin-like geological formation, generally very level, enclosed by steep cliffs. They are created by solution of the limestone and dolomite by rainwater. During the winter period of heavy rains, the "polja" are flooded so that temporary lakes are formed, lasting for many months of the year. "Ponorje" (precipice) is an open, shaft-like aperture, the diameter being narrow as compared with the depth, which often exceeds several hundred meters. They are usually situated near or on the bottom of "polja" and serve as either inlet or outlet channels, changing from one to the other with the rising or falling of the water levels.

(5) Because of the heavy rainfall in the JULIAN KARST region, the "polja" of this region are often inundated. For example, the CIRKNICA "polja" becomes flooded and most of the area becomes a lake

* Reference numbers listed in the Bibliography of the report.

for at least 10 months of the year. An area of 30 km^2 is flooded. The customary period of flooding lasts from October to the end of July. However, inundation of this "polje" lasted for 18 months in 1896-97. The depth of the lake averages 2.5-3 m; occasionally it becomes as deep as 4.0 m. The water flows into and out of the "ponorje" with great rapidity; hence, even in the summer, the conditions of the bed of the CIRKNICA "LAKE" are uncertain. In very dry summers, the lake is completely dried up. Owing to the temporary choking of the "ponorje," it often happens that the inundation of CERKNICA and the neighboring PLANINA shows wide fluctuation from year to year. Systematic cave cleaning now takes place, in both the Yugoslav and the Italian parts of the "KARST" region. This makes the "polje" drain more freely and reduces the extent of the flooded areas.

(6) The cleaning of caves and "ponorje" on one side of the frontier has been known to lead to changes in the flood regime in basins located several miles on the other side of the international boundary. These changes are due to the presence of hitherto unsuspected underground connecting channels. Increases in the intensity of floods in the PLANINA "polje" have sometimes been attributed to cave cleaning in Italy.

(7) The underground waters of the PLANINA and CERKNICA "polja," together with the water of the UNCE wells which flow to VIPAVA and VRHNIK in the LJUBLJANA marshland might be advantageously utilized for hydro-electric power development. (See following paragraph 3, an abstract of Reference 14.)

3. Potential Hydraulic Developments of the SAVA River
(Basis: Reference 14*; "Saopštejna-Sa Prvog Savetovanja Stručnjaka Jugoslavije-O Visokim Branama," 1950)

a. The SAVA River represents a typical case where the construction of high dams in mountainous parts of the river and its tributaries will simultaneously solve the problems of land improvement, power generation, navigation, and flood protection.

b. The plains and flats of the lower SAVA River are regularly flooded despite the efforts of some regional and local communities to protect the land by protective structures. These floods are particularly serious along the BOSNIAN SAVA, where the flooded area covers 78 km^2 and in the regions of MACVA, SREM, LONJSKOG and CRNA POLJA. Only the BID BOSUT drainage project has sufficient flood protection (p. 303, Reference 11). The only solution for prevention of these floods lies in the building of reservoirs in the mountainous parts of the SAVA watershed. These reservoirs could then retain the runoff from the intense precipitation of the ALPS and KARST regions.

c. The total area of land along the lower SAVA River below ZAGREB requiring melioration, is 584 km^2 of which 414 km^2 are situated on the right and 170 km^2 on the left side of the river.

*Reference listed in the Bibliography of the report.

d. The irrigation of these areas would require that at least 60 m^3/sec be withdrawn from the SAVA River during low water periods. The minimum discharges of the SAVA River are as follows:

Location	Minimum Flow (m^3/sec)
JASENOVAC	75
SAMAC	172
SREMSKA MITROVICA	225
BEOGRAD	235

Withdrawal of water for irrigation purposes would entirely eliminate navigation on the SAVA River.

e. The navigability of the SAVA River at low stages is very unfavorable. This was particularly obvious during the 1946-50 period. In 1946, navigation was possible for boats of 180 cm draft only up to ZABREZJA. Further upstream navigation had to be discontinued for boats with normal draft. Normally, SAVA River navigation is possible for boats of 120-150 cm draft; at very low stages, for boats of 100-120 cm draft. Many obstacles are found at KUPINOVA, SREMSKA RACA, SAMAC and in the reach to SISAK-GRADISKA. A 250 cm minimum navigable depth would be required in order to make the SAVA River navigable for barges of 1,000-ton (metric) capacity and 200 cm draft. In order to insure that depth, the minimum discharge below SISAK would have to be increased 62 m^3/sec. Adding that to the 60 m^3/sec required for irrigation, gives 122 m^3/sec to be supplied from retention reservoirs.

f. Following are the possibilities of retention reservoirs in the SAVA region (some of these are already under construction):

River Basin	Storage Capacity (million m^3)
LJUBLJANA	230 (150 at PLANINA plus 80 at CIRKNICA) both fed by underground water
UNA	85
SANA	110
UNAC	115
KUPA	650
DRINA	500

The KUPA and DRINA Rivers have the greatest effect on the navigability of the SAVA River and consequently on the water stages of the DANUBE River below BELGRADE. The purpose of the retention reservoirs planned for these regions are to be primarily for navigation and irrigation and, secondarily, for hydro-electric power.

* Reference number listed in the Bibliography of the report.

EXHIBIT B

ABSTRACTS OF TECHNICAL LITERATURE

ON MOSTE DAM

(Translated from Reference 14)*

*Reference number listed in the Bibliography of the report.

EXHIBIT B

ABSTRACTS OF TECHNICAL LITERATURE

ON MOSTE DAM

1. <u>Introduction</u>.

a. These abstracts were translated and compiled from 5 articles published in 1951 in BELGRADE under the title "Saopstenja Sa I Savetovanja Strucnjaka Jugoslavije O Visokim Branama" (Transactions - The First Meeting of the Yugoslav National Committee on Large Dams, 18-23 September 1950, ZAGREB) and listed as Reference 14 in the Bibliography of this report.

b. The articles referring to Moste Dam are:

(1) Marko, L.: Evacuation of High Water and Dissipation of its Energy at Moste Dam.

(2) Omersa, I.: Experiences Acquired at the Construction of Moste Dam.

(3) Kleindienst, M.: Geological, Geotechnical and Structural Characteristics of Moste Dam.

(4) Chizzl, J.: Statical and Structural Characteristics of Moste Dam.

(5) Podgornik, R.: Injections on Hydro-electric Plant at Moste.

c. The articles were written in 1950, when MOSTE DAM was under construction (the construction work started sometime in 1948). The discussions refer to final plans and laboratory experiments performed on models in the Hydraulic Laboratory of the LJUBLJANA Technical University. (T.V.S.) The present construction status, the mechanical equipment for operation, and power production facilities for the dam are not described in these articles.

d. According to the articles, MOSTE DAM is to be built in two stages. The first stage provides for construction of the dam up to elevation 514.00 m.a.s.l., which is 9.5 m less than the finally planned elevation of 523.5 m.a.s.l.

2. <u>Geological Conditions</u>.

a. MOSTE DAM is located on the SAVA-DOLINKA River astride the gorge known as "KAVOKA TESNAC," near ZIROVNICE in the GORENSKO district.

For the exact location, see Figs. 1 and 3 on Plate 7 of the report or Fig. 9, p 171 and Fig. 4, p 43 of Reference 14. At the dam, the KAVCKA Gorge is 55-56 m deep. (See Fig. 1, p 161 of Reference 14.) The bottom elevation is 474.00 m.a.s. The gorge is only 2 to 4 m wide at the bottom, widening to 18 m at approximately 510.00 m.a.s., and to 35 m at elevation 523.50 m.a.s. (the proposed ultimate elevation of the dam's crest.) In 1910 (while still under Austria-Hungary) this location was selected for construction of a hydro-electric power plant because of structural advantages and also because the land above the damsite was of small value without communications, or other structures which would be destroyed or damaged by rising waters.

b. The so-called main "Savian Break" runs across the location of the dam and extends upstream for about 700 m (see Fig. 2, p 116). A narrow, steep range composed of Triassic limestone extends along the SAVA river bed. The SAVA river has eroded its bed twice across the break and has also penetrated through the limestone crest at the KAVCKA gorge.

c. On the south side of the dam, lies a tertiary chalky clay called "sivica" or "tegel", the surface of which shows a developed erosion. Strata of "sivica" are dispersed along the river bed and along its ridges and are covered by diluvial and alluvial sediments. Subsurface explorations performed on several occasions prior to construction of the dam were unable to determine the thickness of the "sivica" in the SAVA river bed. Drillings and borings on the south side of the dam have gone as deep as 43.5 m below the bottom of the river.

d. On the North, parallel to the limestone range, there is a mass of Triassic dolomite along the whole 590 m of the bottom and left side of the SAVIAN gorge. The dolomite is covered by a stratum of alluvium, but changes into a hard conglomerate where exposed.

e. During investigations it was confirmed that the geology of the tectonic region is more complicated than was originally assumed.

f. The surface of the western part of the break inclines downward towards the southwest. It gradually becomes vertical and is so at the MOSTE DAM gorge. Farther east, the surface reverses its slope and inclines toward the northeast towards the massive KARAVANKA mountains. This predominant break affects the whole tectonic zone, and is apparent by the extensive surface creeps. On the limestone crest, there are visible traces of diagonal slides.

g. The main tectonical movement was accomplished during the Tertiary period, perhaps after the Miocene period. The "sivica" was then formed. At the same time, there occurred a horizontal motion as a result of horizontal orogenic forces. The limestone near the upper part of the break was compressed into "sivica." Other changes in the limestone masses were also produced. With that in mind, we can interpret the origin of the folded mountainous zone that is wedged under the limestone block. That zone is composed predominantly of "sivica" slabs with compressed blocks of limestone and Tertiary sand soil.

h. The origin of that mixed zone and of the mass of limestone near the brook has long been the subject of discussions among the geologists. Many vertical and inclined drillings have been made. Finally, a large excavation into the core of the mass was undertaken in order to determine the petrographic and geotechnic characteristics of the ground in order to evaluate its stability and permeability.

i. The geological survey of the site of MOSTE damsite began in 1920 under Prof. M. Lukovic as the main consultant. Subsurface explorations by means of deep drilled bores, excavations and diggings were performed in 1931, 1940, and 1946. The geotechnical problems as well as the problem of ground consolidation by the injection method were in the hands of Dr. L. Smaljo, Dr. Savic, and a French expert, Dr. A. Mayer. The consolidation of the foundation by the injection method was executed by the Swiss firm "Swissboring" with the cooperation of the Yugoslav firm "Elektrosond."

j. All the many expert consultants agree that construction of MOSTE DAM is geologically and technically very difficult. At the beginning of the project, most of them were very optimistic; but later the opinions became divided. Finally they did decide to proceed with the construction as being practicable. However, final decisions are still pending on the questions of required reservoir storage, method of accomplishment and extent of consolidation work on the dam.

k. For foundation purposes, 24 exploratory bores with a total length of 1,438 m were made. The consolidation of the ground by the injection method was performed by injecting 650 tons of cement into 20,000 m of bores. In order to seal the junction of the dam with the walls and sides of the canyon, 1,700 m of borings were injected (see Fig. 3, p 169 and Figs. 1, 2, 3, pp 176, 177 of Reference 14).

3. <u>Hydrologic Conditions.</u>

a. The drainage area of the SAVA River above the dam covers 325 km^2, and is characterized by a very variable run-off intensity. On the basis of hydrologic data accumulated during the last fifty years (since 1896) at the JESENICE and RADOVLJICA gaging stations, the following values for SAVA River flows were determined:

Flow	m^3/sec
Yearly low water	7
" mean "	16
" high "	115
Average 5 year high water	150
" 20 " " "	250
" 100 " " "	400
" 1000 " " "	700

The highest recorded high water (in fall of 1926) was 350 m^3/sec discharge.

b. The storage capacity of the lake behind the dam will be 6.89 million m^3 at the 523.50 m.ü.A. final elevation of the dam crest. Of this, 5.46 million m^3 is to be used for power generation (with a usable head of 13.5 m). In the final stage of development, the height of the dam will be 46.5 m, the length of the lake will be 4.5 km, and the area covered with be 680,000 m^2.

c. As mentioned above, the dam is being built in two stages. The first stage provides for the dam crest at elevation 514.00 m.ü.A. At this stage, which is 9.50 m lower than the ultimate stage, the reservoir capacity will be only 2.3 million m^3 and the area of the lake behind the dam 270,000 m^2.

d. Because of the importance of the dam and also to safeguard the industrial enterprises located downstream, it was decided to use 700 m^3/sec as the design discharge for the outlet structures of the dam. For economic reasons, however, the alternative structure finally selected for construction, has an outlet structure that by-passes the dam through a 5.10 m diameter tunnel and carries only 130 m^3/sec. The remaining 570 m^3/sec of the design discharge would be carried over the top of the dam. The 44 m long curved crest extends over the slopes of the gorge on both sides. A 4.00 m head (527.5 m.ü.A. elevation) on that length of crest is sufficient to pass the required discharge. (See Figs. 2 and 4 on Plate 7 of the report or Figs. 3 and 4, p 43 of Reference 14).

4. Structural Features.

a. MOSTE DAM is a gravity type dam with a curved crest. (See Figs. 3 and 4 on Plate 7 of the report or Fig. 2 on p 168 of Reference 14). In the final stage, the total volume of masonry will be 26,500 m^3 (corresponding approximately to 260 m^3 of impounded water per 1 m^3 of masonry). The directing vertical axis of the circular dam coincides with the axis of the cylindrical upstream surface of the dam. That radius is 30.00 m. This axis is also the axis of the conical downstream surface of the dam in the upper part, between the crest and the elevation of 495.00 m.ü.A. At this elevation, the radius of the downstream surface is 16.24 m and its shape changes from a cone into an oblique cylinder of the same radius. From there to the elevation of 487.00 m.ü.A., the surface is a hyperbolic conoid, followed by a plain cylindrical surface of 29.52 m radius with a horizontal axis, finally reaching the bottom of the stilling basin at 477.00 m.ü.A. elevation. (See Plate 7 of the report).

b. The dam is constructed in concrete monoliths to minimize movement due to temperature changes. The dam crest is at 523.50 m.ü.A. and is designed for a 4.0 additional head of water (527.50 m.ü.A.) at the highest possible flood conditions. The crest is provided with 2 directing concrete ribs to concentrate the overflow into the middle of the downstream surface of the dam. The structure of the overflow crest was tested in the T.V.S. laboratory at LJUBLJANA (see Figs. 6 & 7, p 43 of Reference 14).

c. The stilling basin has a trapezoidal shape, 30.0 m long, increasing in width from 15 to 20 m. The floor elevation is 477.00 m.ü.A. It ends with a 5 m high energy-dispersion sill rising in three equal steps

each 1.67 m high and 3.34 m wide. (See Fig. 4 on Plate 7 of the report or Fig. 9, p 44 of Reference 14).

5. Outlet Conduit.

a. The critical features of the outlet conduit are shown on Fig. 2, Plate 7 of the report or on Fig. 10, p 43 of Reference 14. The entrance is a funnel-shaped pyramid. At its smallest cross-section the area is equal to the gate opening. The discharge capacity is 130 m^3/sec at normal head. Downstream from the gate the roof of the conduit abruptly rises to 5.1 m in height. The conduit widens and changes shape to a 5.10 m diameter circular tunnel. A shaft inclined at a 65-degree angle from horizontal, joins the conduit downstream of the gate transition. This permits undisturbed entrance of air. (See Fig. 3, Plate 7 of the report or Figs. 4 & 10, pp 42 and 44 of Reference 14). The outlet tunnel is designed to allow the development of a necessary counterpressure before releasing the water into the river bed. With this arrangement at low flow, a hydraulic jump appears near the restricted gate opening. Also the length of the jump is short and is stabilised at one place by this arrangement. At restricted openings, the flow at the outlet is under pressure and its velocity decreases rapidly from 22 m/sec before the jump to 6 m/sec after the jump. This arrangement thus insures that the flow through the curved tunnel is entirely symmetrical at restricted openings.

b. The energy at the exit of the conduit is reduced by two dissipators, located at one-[illegible] of the stilling basin length. Downstream of these is a lower concave sill. At the lower end of the basin, there is also vertical end sill. The dissipators are 2.50 m high, 1.25 m wide, and are bevelled in order to decrease the effect of cavitation. The lower sill is 1.60 m high, and 2.00 m wide. The end sill is 4.00 m high. Figs. 11 to 17, pp 45 and 46 of Reference 14, show pictures taken of laboratory experiments on a model of this outlet structure.

6. Service Bridge.

a. Two alternatives were proposed for the bridging of KAVOKA GORGE at MOSTE DAM:

(1) A bridge upstream from the dam at the extension of the existing very steep (14%) highway.

(2) A bridge on top of the dam.

b. The second alternative provides for a bridge with 4 spans and 3 pillars, 2 of which would be located on the two directing concrete ribs mentioned above and the third pillar would be built in the middle of the crest. This alternative involves an additional 1.0 m increase of hydraulic head on the crest because of the interference of the pillars; therefore, the first alternative was preferred.